

The University of Chicago

VEGETATION OF THE CHIMNEY
ROCK AREA, PAGOSA-PIEDRA
REGION, COLORADO

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY

1932

By

HAZEL MARGUERITE SCHMOLL

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

1935

The University of Chicago

VEGETATION OF THE CHIMNEY
ROCK AREA, PAGOSA-PIEDRA
REGION, COLORADO

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY
1932

By
HAZEL MARGUERITE SCHMOLL

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS
1935



ACKNOWLEDGMENTS

Sincere appreciation and thanks are extended to Dr. Henry C. Cowles and Dr. George D. Fuller of the Botany Department of the University of Chicago for advice in carrying on the work; and to Dr. Aven Nelson, Dr. E. B. Payson, Dr. C. R. Ball, Dr. A. S. Hitchcock, Mrs. Agnes Chase, Dr. H. M. Hall, Dr. F. W. Pennell, Mr. George E. Osterhout, Miss Joyce E. Hedrick and Mr. E. Bethel for the determination of special plant groups. Dr. Payson determined the greater number of the plants collected in 1924, and Dr. Nelson most of those collected in 1931.

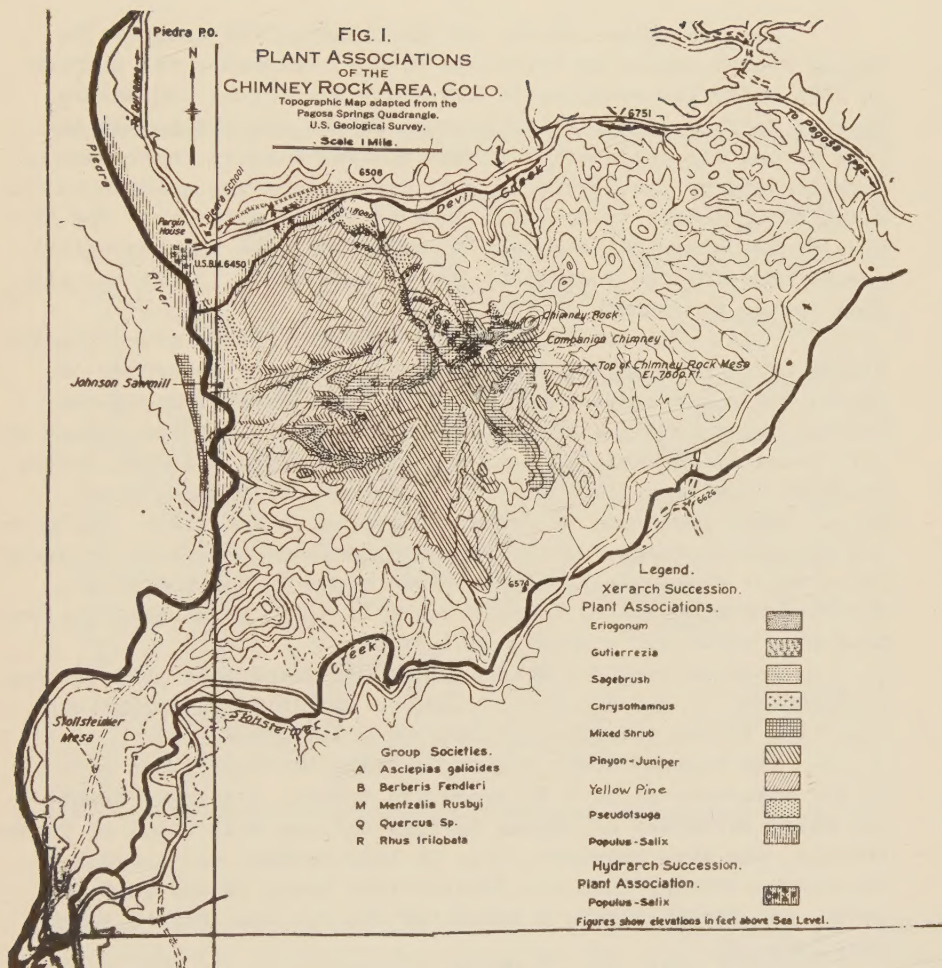


Digitized by the Internet Archive
in 2026

https://archive.org/details/IA41548814_0055

TABLE OF CONTENTS

Introduction	2
Geology	4
Topography	5
Climate	5
Temperature	8
Frostless season	10
Precipitation	12
Snowfall	13
Wind	13
Humidity	13
Sunshine	14
Soils	14
Geologic origin	14
Factors in rock disintegration	14
Humus content	14
Soil water	15
Salts	15
Vegetative life zones	16
Plant associations	17
Habitat	17
Succession	18
Methods of investigation	19
Quadrat studies	19
Raunkaier's law of frequency	20
Coverage	21
Xerarch succession	21
1. Lichen association	21
2. <u>Eriogonum</u> association	21
3. <u>Gutierrezia</u> association	24
4. Sagebrush association	24
5. Mixed shrub association	25
6. Pinyon-juniper association	30
a. Top of Mesa	32
7. Yellow pine association	34
8. <u>Chrysothamnus</u> association	39
9. <u>Pseudotsuga</u> association	41
Hydrarch succession	43
10. <u>Populus-Salix</u> association	43
Plant list	46
Summary	54
Bibliography	57



VEGETATION OF THE CHIMNEY ROCK AREA,
PAGOSA-PIEDRA REGION, COLORADO

INTRODUCTION

The ecological survey of the Chimney Rock area of the Pagosa-Piedra region of Archuleta County, Colorado, was started in 1924 under the auspices of the State Historical and Natural History Society of the State Museum, Denver, Colorado. At the time of the discontinuation of the Natural History Department of this Society by the State, in 1925, permission was granted by its Board of Directors to use this data as thesis material. The purpose of the botanical work was to supplement the archaeological report made for the Society by Dr. J. A. Jeancon (8) in the same area during the summer of 1921.

Plant collections were made over the entire area from the middle of June to late in July, and again during September of 1924. A reconnaissance trip was made at this time throughout western Colorado and other places to aid in the interpretation of life zones and associations of the area surveyed. The itinerary included Mesa Verde National Park, Durango, Silverton, Ouray, Delta, Grand Junction, De Beque, Leadville, Buena Vista, Florence and Colorado Springs. Quantitative studies of the flora by means of quadrats were made the first three weeks in September 1931. The D. D. Pargin Ranch, located one mile south of Piedra, was the base from which all work was conducted.

Manuals used for making plant determinations and checking distribution of species were: Coulter and Nelson (4), Rydberg (14, 15), Wootton and Standley (21), and Tidestrom (19).

The Pagosa-Piedra region in which the survey was made is in the west-central part of Archuleta County, Colorado, twenty-two miles southwest of Pagosa Springs and one mile south of Piedra. Briefly, the area surveyed (Fig. 1) lies between Devil Creek to the north, Chimney Rock and Stollsteimer Creek to the east and south, and Piedra River, a branch of the San Juan River, to the west (Fig. 2).

The localities in which plants were collected and the habitats studied include the area from a point one mile north on the Piedra River from the place where Devil Creek joins the Piedra River southeast one-half mile along the east side of the Piedra

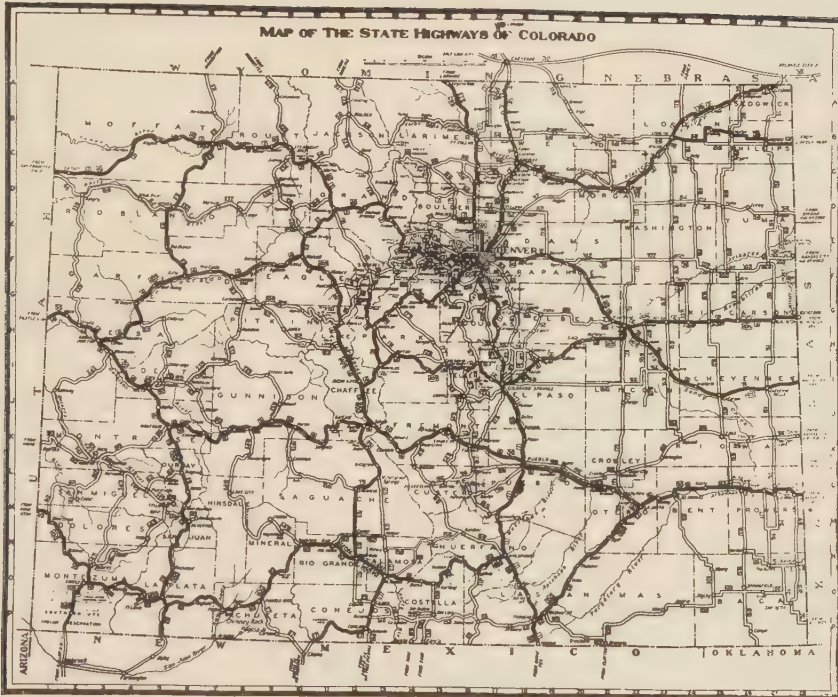


Fig. 2. Map of Colorado locating the Chimney Rock area in Archuleta County in the southwestern part of the State.

River; thence one mile east and to the north of the road paralleling Devil Creek to the place where a branch road turns to the southeast and joins the Chimney Rock trail to the base of the "Companion" Chimney; thence southeast along the Chimney Rock Mesa to the second gulch south of Devil Creek which runs west to the Piedra River; and north along the east side of the Piedra River.

GEOLOGY

No geological report has been published on the Chimney Rock area. Specific information was obtained through a communication from Dr. W. C. Mendenhall of the United States Geological Survey which states that

"The rock capping Chimney Rock Mesa (referred to on the map in Bulletin 341 [Gardner, 7] as "Piedra Parada") is the Pictured Cliffs sandstone and underlying it is the Lewis shale, both of Upper Cretaceous age."

The Pictured Cliffs sandstone.--The chimneys and mesa top are capped by this light yellow, homogeneous, loosely cemented sandstone. This formation forms an escarpment on the west side of the Piedra River, and the Chimney Rocks and Chimney Rock Mesa seem to be an erosion remnant of this escarpment cut off by the Piedra River. At the southwestern extension of the Chimney Rock Mesa the sandstone weathers into round boulders. Overlying this sandstone are a few rectangular blocks of brown sandstone which show joint fracturing. Exfoliation due to sudden temperature changes is a common phenomenon wherever the light yellow sandstone is exposed. Stones used in the building of the Indian ruins, and talus slopes at the sides of the mesa show that the sandstone is thin bedded and weathers into thin rectangular blocks. Evidence of dry climate is seen in the deposit of alkali salts on the east face of the Chimney Rocks.

On the whole the strata dip slightly to the southeast, but the gradually descending slope is to the southwest. Below and immediately to the north and west of Chimney Rock Mesa the cap of harder sandstone has worn away leaving shale hills which in some places have disintegrated sandstone rocks scattered about on them.

Lewis shale.--This is a fairly homogeneous mass of dark gray to greenish gray shale in which occur one or more thin hard strata. The exposure in this region is at least one thousand feet in thickness. The weathering seems more rapid than that of the sandstone. The ultimate product of the first disintegration is of a rather finer and looser texture than that of the disintegrated sandstone.

TOPOGRAPHY

The Chimney Rock country, for the most part, is one of mesas with stream-cut valleys, ranging from 6,450 to 7,902 feet in altitude. The Chimney Rocks themselves and the highest part of the Mesa stand several hundred feet above the surrounding country (Fig. 3). Chimney Rock has an elevation of 7,902 feet, while the altitude of the highest part of the Mesa is 7,600 feet.

The gulches leading in all directions from Chimney Rock Mesa are v-shaped and cut through the sandstone cap and shale to a depth of several hundred feet.

Perpendicular rock cliffs 25 to 200 feet high surround the Chimney Rock Mesa and its extensions. The talus slopes which extend downward from the base of these vertical cliffs on both the northwest and southeast sides of the Mesa are also very steep. A measurement of the northwest slope taken along the trail about 25 feet from the base of the cliff gave a 70° angle.

From observations in this region it is obvious that the south-facing slope has the warmest air, the greatest heat accumulation during the day, the least soil moisture, the lowest relative humidity, and the driest habitat; the west-facing slope is next in warmth of air and accumulated heat, and has slightly more soil moisture and a less dry habitat; then follow the east- and north-facing slopes with less heat and more moisture.

CLIMATE

Based upon the assumption that plants are indicators of climate, two life zones are present in the area surveyed, the foothill or yellow pine zone (Ramaley, 12) represented primarily by the yellow pine climax association, and the upper sonoran or pinyon-juniper zone represented by the pinyon-juniper climax association.

Climatological data for temperature, precipitation and wind were assembled from two towns about equidistant from the Chimney Rocks, but located in these life zones (Day, 6; Sherier, 17). The towns are Pagosa Springs, in the foothill or yellow pine zone, having an altitude of 7,108 feet, and about 22 miles northwest of the Chimney Rocks; and Ignacio in the upper sonoran or pinyon-juniper zone at 6,425 feet altitude about the same distance southwest of the Chimney Rocks. It is recognized that the data from these stations can give only an approximate estimate of climatic conditions as they may exist in this particular region for reasons discussed more fully later (Table I).



Fig. 3. View of the Chimney Rock area from the northwest. From left to right in the distance are: Chimney Rock, "Companion" Chimney Rock, Chimney Rock Mesa. Devil Creek, in the immediate foreground, is bordered by the Populus-Salix association. Hills to the south of this are covered by yellow pine forest. The steep north-facing slope of the Chimney Rock and Chimney Rock Mesa beyond show mixed shrub and Pseudo-tsuga associations.

TABLE I
CLIMATOLOGICAL DATA *

Climatological data	Plant associations	Length of record (yrs.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Mean temperature F.	Yellow pine Pinyon- juniper	13	17.85	22.65	30.35	40.48	46.33	55.05	61.40	59.68	52.78	42.13	30.10	19.95	39.90
Average maximum temperature F.	Yellow pine Pinyon- juniper	17	21.62	26.80	36.14	44.20	52.23	61.23	67.65	66.03	57.83	46.90	35.29	25.51	45.18
Average minimum temperature F.	Yellow pine Pinyon- juniper	11	40	45.3	53.9	59.1	68.0	78.0	81.9	79.7	73.5	61.8	51.6	36.3	60.8
Average minimum temperature F.	Yellow pine Pinyon- juniper	9	37.5	42.3	50.5	59	68.7	80.8	83.9	82.1	76.2	64.2	52.0	41.1	61.5
Lowest temperature F.	Yellow pine Pinyon- juniper	11	-0.3	3.2	14.6	24.9	27.8	34.9	45.0	44.0	36.5	24.5	14.1	0.4	22.5
Highest temperature F.	Yellow pine Pinyon- juniper	9	5.3	13.0	21.1	28.1	34.0	41.7	50.9	48.9	40.7	29.1	18.1	11.5	28.5
Average precipitation inches	Yellow pine Pinyon- juniper	11	-57	-39	-25	9	11	20	25	31	15	-5	-12	-35	-39
Average snowfall inches	Yellow pine Pinyon- juniper	9	-27	-22	-9	0	17	20	34	32	26	14	-10	-22	-27
	Yellow pine Pinyon- juniper	11	52	53	68	77	89	92	95	91	86	85	74	58	95
	Yellow pine Pinyon- juniper	9	60	64	69	75	88	94	97	94	89	82	69	58	97
	Yellow pine Pinyon- juniper	14	2.57	2.09	1.75	1.80	1.42	0.95	3.39	2.64	1.96	2.87	1.15	1.64	24.23
	Yellow pine Pinyon- juniper	17	1.06	1.08	1.39	1.37	1.08	0.91	2.46	2.17	1.72	1.36	1.02	1.07	16.69
	Yellow pine Pinyon- juniper	10	22.20	26.90	11.60	4.80	1.40	0	0	0	0.40	3.9	6.90	20.20	98.30
	Yellow pine Pinyon- juniper	8	13.90	9.10	3.20	1.20	0.20	T	0	0	0	0.2	3.90	9.80	41.50

*Climatological data for yellow pine (Pagosa Springs, 7,108 feet altitude) and pinyon-juniper (Ignacio, 8,425 feet altitude) associations in the Pagosa-Piedra-Ignacio region. The records are from the establishment of each station to 1930 inclusive.

Where possible, climatological data were obtained from the establishment of these stations through 1930. Mean maximum, mean minimum, lowest, and highest monthly temperature data were available for only 11 years for Pagosa Springs and for 9 years for Ignacio. These were for the years immediately preceding and including 1922. In the case of the highest and the lowest temperature only the month and day of the occurrence was recorded for these stations after 1922. Mean monthly temperature data through 1930 was recorded for 13 years at Pagosa Springs and for 17 years at Ignacio. Records for Pagosa Springs from 1923 to 1928 inclusive were wanting. The Ignacio records are from 1914 to 1930 inclusive.

Mean monthly precipitation in inches of rainfall was available for 14 years (1891, 1907-1917, 1929, 1930) for Pagosa Springs, and 17 years (1914-1930) for Ignacio.

Average monthly and annual snowfall in inches was recorded only through 1922 for both stations, for 10 years at Pagosa Springs and 8 years at Ignacio.

The nearest station for relative humidity and sunshine data was at Durango, at an altitude of 6,550 feet. Durango is about 45 miles northwest of Piedra. In each case records were kept for 9 years previous to and including 1922 at this station.

A more detailed discussion of the climatic factors for temperature, precipitation, humidity, wind and sunshine follows.

Temperature.--Data for air temperatures only are given. Mean annual temperatures are 39.9°F. for yellow pine zone and 45.18°F. for pinyon-juniper zone. The summer months of June, July and August are the hottest for both zones. Mean annual temperatures for the growing season, May to September, are 55.03°F. for the yellow pine zone and 60.8°F. for the pinyon-juniper zone. July has the highest recorded temperature of 95°F. for the yellow pine zone, and 97°F. for the pinyon-juniper zone. The lowest mean minimum temperatures for both zones occur in January; however, the lowest recorded temperatures are -39°F. in February for the yellow pine zone and -27°F. in January for the pinyon-juniper zone.

The hythergraph (Fig. 4) prepared from mean monthly temperatures and mean monthly precipitation shows graphically the monthly sequence of temperatures and the temperature-precipitation relationships.

The data here given for the average minimum temperatures (Table I) confirm Pearson's (11) statement that low temperature becomes more moderate as the distance from the mountains increases. That the temperature in both zones is lower than in Arizona may be accounted for by the close proximity of the area to the high

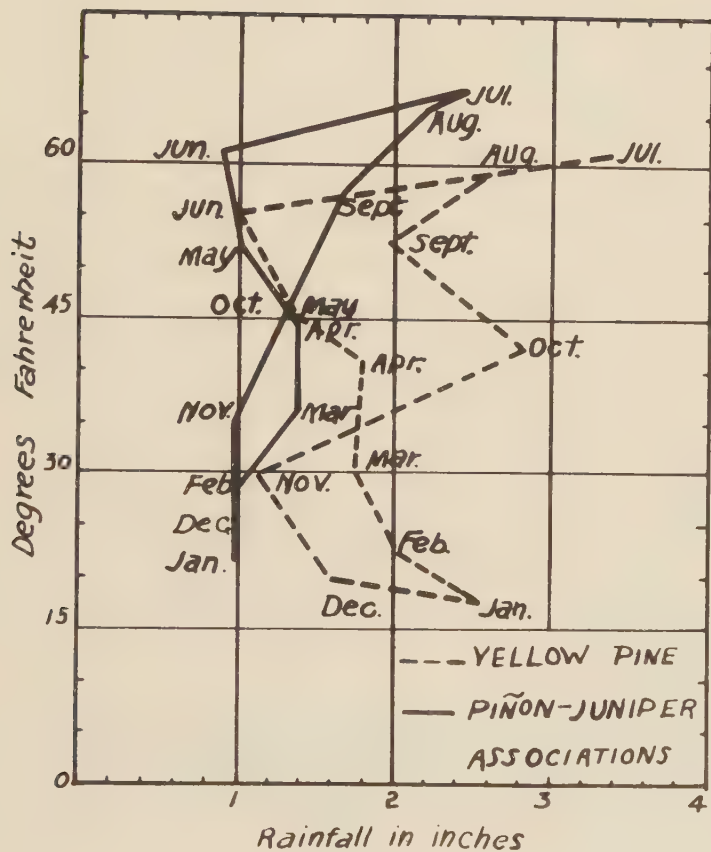


Fig. 4. Hythergraphs for yellow pine and pinyon-juniper associations at Pagosa Springs and Ignacio, Colorado.

San Juan Mountains.

The total annual difference of 5.22°F. for the average mean temperature and 6.06°F. for the mean minimum temperature between the yellow pine and pinyon-juniper zones coincides with the general statement that temperature decreases as altitude increases. The difference in altitude between the two stations is 683 feet. The steepness of the curves (Fig. 5) in these zones represents a rather wide seasonal range in temperature. The total annual difference of the mean maximum temperature for the two zones, however, is 1.6°F. A study of the curve for the mean monthly maximum of each of these zones shows a temperature inversion in which the temperature is 2 to 3 degrees higher in the yellow pine zone than in the pinyon-juniper zone for the months of January to April, and that the temperatures for April and November coincide. This inversion of temperature, which means that the temperature increases locally with altitude instead of decreases, is explained by Robbins (13) as follows: "as a result of air drainage, the valleys and canyon bottoms are cooler than the adjacent hillsides." He states that this is a common phenomenon in the mountains and occurs in spring and autumn. Bates (1) speaks of its frequent occurrence during the winter months and cites Wagon Wheel Gap as an example. Pearson's (11) climatological data for north-central New Mexico shows a slightly greater but more uniform difference in mean annual temperature between the two zones than in the Chimney Rock area. He has as differences for the mean 5.86°F. ; for the minimum 6.63°F. and for the maximum 5.05°F. , each of which gives a regular curve.

Frostless season.--For reasons given by Pearson (11) which coincide with my own observations, the growing season will be regarded as covering the period from May to September inclusive and not as coinciding with the frostless season. The average growing season temperature for the yellow pine zone is 55°F. , and for the pinyon-juniper zone 60.8°F.

The following table gives the dates of the last spring frost and first autumn frost, and the consequent length of the average frostless season over a period of years.

Those living at the Pargin Ranch, 6,450 feet altitude, give May 20 to June 1 as the usual time for the last spring frost. A heavy frost occurred, however, on June 24, 1924.

Climatological data in the Chimney Rock area compare closely with those for areas in north-central New Mexico cited by Pearson (11). He finds that in the western yellow pine and pinyon-juniper forest types the growing season begins earlier than the last frost and that the western yellow pine, pinyon and junipers make their growth in height during May and June, while frosts are

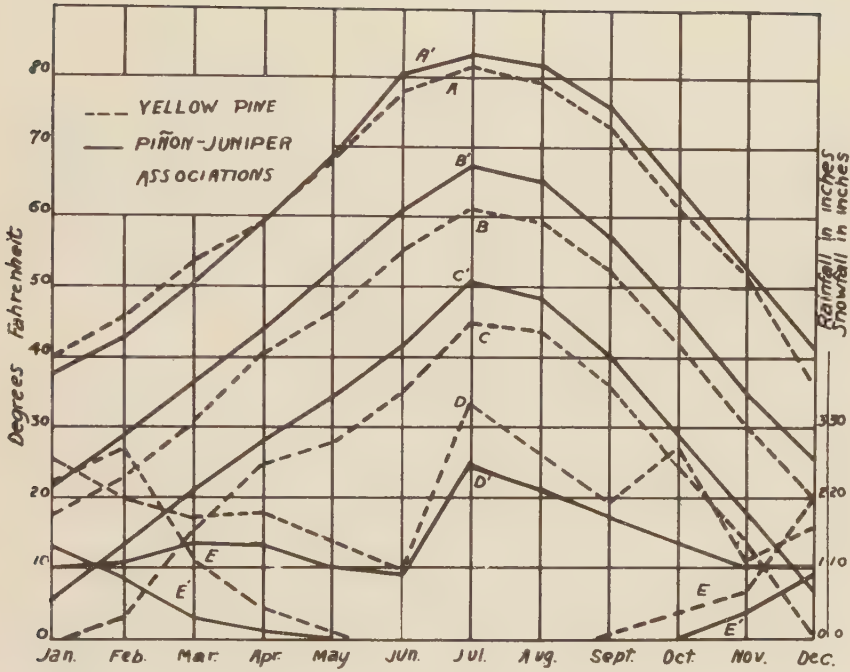


Fig. 5. Graphs of average monthly maximum A, A', mean B, B', and minimum C, C' temperatures; and for mean monthly precipitation D, D' and snowfall E, E' for the yellow pine and piñon-juniper associations.

Station and zone	Alt. (feet)	No. of years record	Average date of frost		Length of average frostless season
			Last spring	First autumn	
Pagosa Springs yellow pine	7,108	12	June 25	Sept. 12	75
Ignacio pinyon-juniper . . .	6,425	17	May 26	Sept. 18	105

common. Elongation and diameter growth of these conifers are complete by September first; herbaceous plants, however, continue their activity until a very heavy frost. During the spring when frosts occur every night he says that Poa fendleriana and Thlaspi fendleri, which occur in the western yellow pine zone, "make their major vegetative growth, blossom and mature their fruit." These two latter plants occur in the yellow pine zone of the Chimney Rock area.

Because Bouteloua oligostachya was found in the pinyon-juniper forest blossoming early in September it is probably true that its main vegetative activity occurs after the June drought and at the beginning of the heavy rainfall of July.

Precipitation.--That the mean annual rainfall (Table I) increases with altitude is clearly shown in the yellow pine zone data with a rainfall of 24.23 inches, and in the pinyon-juniper zone with a rainfall of 16.69 inches.

The seasonal distribution of the mean average rainfall for the yellow pine zone is 38% for the winter months from November to March and 43% for the growing season from May to September, and for the pinyon zone 33% for the winter months and 50% for the growing season.

Winter precipitation is said to decrease as we go eastward whereas spring and summer rainfall increase. Leaving aside the consideration of altitude we find that the average precipitation from April to September in the yellow pine zone is 50% and in the pinyon-juniper 58% of the total for the year compared with 70% for the same period given by Steiger (18) for the prairie area near Lincoln, Nebraska.

June is the month of least rainfall in both forest zones. Temperature is almost at a maximum in June, so that drought conditions prevail. This drought is followed by July which has the greatest precipitation of any month in the year, the average for the yellow pine zone being 3.39 inches and for the pinyon-juniper

zone 2.46 inches. Despite the high precipitation, together with the highest temperature during July which make for maximum growth, heavy run-off, due to rugged topography, obviously high evaporation, and heavy clay soil would seem to offset the availability of a large amount of this precipitation.

The precipitation curve (Fig. 5) for the yellow pine zone has three peaks. The greatest precipitation occurs in July, 3.39 inches; October, 2.87 inches; and in January, 2.57 inches. The latter high point is due to heavy snowfall. The greatest precipitation for the pinyon-juniper zone occurs in July, 2.46; and in August, 2.17.

Abrupt changes in the vegetation, decided annual fluctuations of precipitation and a wide range of daily temperature seem best explained by the varied and rugged topography and the geographic location of the Chimney Rock region. The annual precipitation record covering a period of 16 years for Ignacio shows a fairly uniform alternation of wet and dry years.

In 1924 there was no rain at the Pargin ranch from April first to July fourth, and only one day of rain in September. Up to this time it was said to be the driest year known to pioneers. Climatological records at Ignacio show that 1917 had a lower rainfall, but there was a difference in its seasonal distribution.

Snowfall.--Snowfall (Fig. 5) like rainfall increases with altitude, and varies from year to year. It is especially high in the yellow pine zone where the highest average annual monthly snowfall occurred in February. The annual average snowfall for the yellow pine zone was 91.3 inches compared with 41.5 inches in the pinyon-juniper zone.

Since there is practically no wind in this region in winter the ground retains a uniform snow cover which protects lower vegetation from drying and permits the accumulation of moisture in the soil which provides the plants with moisture during the dry months of May and June.

Wind.--The western slope of the Continental Divide differs from the eastern slope in its lack of winter winds. The prevailing winds in the Pagosa-Piedra region are from the west or southwest, the direction varying somewhat from year to year. The station at Ignacio gives the winds from 1923 to 1927 as prevailing from the west and from 1928 to 1930 from the southwest.

Humidity.--The average annual relative humidity for Durango is 75%. The winter months, because of the lack of wind and the presence of a snow cover, have a very high relative humidity, varying from 81% for December and January to 79% for November and February. During April, May and June, when the rainfall is least, it is rather low.

Sunshine.--The annual average sunshine for Durango is 75%. The months having the highest percentage of sunshine were those with the lowest rainfall, namely, June, 84%; September, 81%; and October, 80%.

SOILS

No specific study was made of soil profile but some observations were made on the physical composition of soils. Except for a few remarks here given on geologic origin, factors in rock disintegration, humus content, soil water, salts, and a few topographic and climatic factors necessary to the discussion, this topic will be discussed under the various plant associations.

Geologic origin.--Most of the soils in this region are derived from the disintegration of sedimentary shales and sandstones which give rise to clay and fine sandy soils, the clays predominating throughout the entire area. Those weathering from the sandstone were yellowish brown in color and those from the shales of a gray color.

The surface of the steep slopes of Chimney Rock Mesa consists of varying amounts of flat rocks and a colluvial soil, the amount of soil depending upon whether it was at the base, middle or summit of the slope.

Factors in rock disintegration.--Extremes of daily temperature and pressure of freezing water are doubtless the more important factors which cause the common exfoliation of the sandstone on Chimney Rock Mesa, and the breaking up into thin flat rocks which are so abundant upon the upper part of the steep slopes on either side of the mesa. Occasionally rounded forms of rocks or "bosses" were found, particularly on the exposed rocks to the southeast and southwest ends of the Chimney Rock Mesa.

On the top of Chimney Rock Mesa pinyons, junipers, shrubs and herbs were seen forcing their way between the crevices of the sandstone. This would permit other physical forces to hasten disintegration of the rock.

Humus content.--The amount and richness of humus varies from practically none in the exposed shallow soil habitats like the Chimney Rock Mesa through the decreasingly open plant associations to a cover of an inch or more in the most mesophytic associations like those of Pseudotsuga and Populus-Salix.

Soil water.--The aridity of the climate is evident from the intermittent character of all the streams except the Piedra River and the interrupted flow of seepage water in the canyons. Hence, it is concluded that the ground water must be far below the surface. This would necessitate the development of very long,

deep roots by the plants if they are to avail themselves of this water. Bates (1) tells us that all of the coniferous trees listed for this region have deep roots. Devil Creek was completely dry except for springs or seepage water near the point where it empties into Piedra River. The slope of the strata here is very gentle and water moves slowly through the slate. That the base of the slope provides more moisture than the upper part is seen in the greater density of the plant population at the base.

The run-off, due to the steepness of slope and the fine texture of the soil, is considerable and rapid, causing a large amount of erosion. The effect of run-off on soils of different texture is best seen on the terrace north of Devil Creek.

Salts.---Alkali salts do not appear on the surface of the soil or rocks north of the Chimney Rocks, but are abundantly evident on the vertical south face of the Chimney Rocks and on the surface of the soil in the desert-like valley along Stollsteimer Creek to the east of the Chimney Rock Mesa. The presence of these salts indicates a light rainfall and a high mineral content of the soil.

VEGETATIVE LIFE ZONES

Two life zones are represented in this area, viz., the foothill zone (Ramaley, 12) and the upper sonoran (Rydberg, 16). Rydberg (15) gives the altitudinal limits of the foothill zone in Colorado as 6,000 to 8,000 feet, and the upper sonoran zone as 4,500 to 6,000 feet. The foothill zone of this area comprises the upper stretches of the foothills, mesas and plateaus which project westward from the high San Juan Mountains. Since the area does not seem to lie within the altitudinal range of the upper sonoran zone, and therefore seems to be a zonal reversal, the only explanation for its floristic occurrence here must be that it is due to the extension of the mesas westward into the desert regions and that plants migrate from the lower slopes of these mesas or ridges to the higher elevations on the steep, warm southwestern-facing slopes. The deficiency of moisture together with the high temperature would permit only the upper sonoran type of plants to grow here. This conclusion is substantiated by Cary (2) who shows the influence of exposure and steepness of the slopes, and their effects in extending the vertical limits of life zones in southern Colorado in the following table.

The two belts, "(1) pine belt, the highest, and (2) chaparral belt," of which Rydberg (16) speaks are represented in the foothill zone. This is frequently referred to as the yellow pine zone; Pearson (11), however, uses the term western yellow pine

Zones	Southern Colorado	
	Northeast exposure	Southwest exposure
Upper Sonoran	Feet To 6,500	Feet To 7,800
Transition	6,500 to 8,000	7,800 to 9,000

zone. The yellow pine, Chrysothamnus, Gutierrezia, and sagebrush associations comprise the "pine belt" in the Chimney Rock area. The mixed shrub association represents the "chaparral belt." The mixed shrub association occurs above the yellow pine association on the north-facing slope of Chimney Rock Mesa. This is a case of reversal so far as their altitudinal relationship is concerned, but it is orthodox in that the mixed shrub association lies between the yellow pine and pinyon-juniper associations. On the southeast-facing slopes of the Mesa the mixed shrub association alternates with the pinyon-juniper association of the upper sonoran zone.

The flora on the top of the Chimney Rock Mesa and on the dry south- and southwest-facing shale ridges of the surrounding country belong to the upper sonoran zone. The upper sonoran zone is in places referred to as the pinyon-juniper zone.

In comparing the climatological data of the foothill zone of this region with the transition zone of Merriam and the upper sonoran zone with his upper austral, I find that his temperatures are very much higher than they are for this area. This is in corroboration of the findings of Rydberg, for he believes that the transition zone of Merriam applies only to the transition, boreal and austral zones of the East.

PLANT ASSOCIATIONS

Nichols' (10) definition of an association as "a piece of vegetation" which "must be essentially similar throughout its extent in physiognomy, ecological structure, and in floristic composition" has been followed in determining the plant associations present in the area studied. Each association has been named from the dominant species within it. Where it is well known, the common name of the plant has been used; otherwise the generic name has been employed.

Where groups of subdominant species occur within the association they have been termed societies.

Habitat.--The diversified topography results in sudden changes in the climatic, physiographic and biotic factors of the habitat. This has its direct effect upon the vegetation thereby permitting quick recognition of plant associations and the tracing of plant succession comparatively easily. Except for the biotic factors of the habitat the general observations on the climatic and physiographic factors have been discussed. Any specific effects of these factors upon plant life will be discussed under the individual associations.

Biotic factors are those that have to do with the activities of plants and animals. Only the activities of man noted in the cultivation of land, grazing, lumbering and fire, will be considered at this time. The land cleared for irrigated agriculture is only a small area in the flood plain between Devil Creek and the Piedra River. In fencing the cultivated area a narrow strip along Devil Creek has been left in its native condition. Here the vegetation is dense. During the summer of 1924 sheep grazed the Chimney Rock Mesa from its highest point to the southeast and southwest. No sheep were seen during 1931 and the vegetation indicated no disturbance from that source. Cattle and horses grazed the area between Devil Creek and the base of the Chimney Rock Mesa in 1924 and 1931. The grazing in 1931 was exceedingly light, and grasses not previously collected were found. The larger amount of grazing and general destruction of herbaceous plants in 1924 was due to the use of horses in connection with the lumbering operations of a sawmill in this vicinity.

Fire has not been a major disturbing factor in the memory of the inhabitants. A fire of some acres to the south and east of the Johnson sawmill during 1924 was the only sign of destruction from this cause. While this was primarily a ground fire which burned the ground cover and lower shrubs, it destroyed quite a number of cottonwood and pine trees. The habitat was so modified by burning of the humus in many places that the effects of the burn would be retrogressive and only the most xerophytic plants would be able to establish themselves at first.

Succession.--The trends of the succession are both retrogressive (Cowles, 5) and progressive. Biotic succession, so far as the effect of plants upon one another is concerned, is progressive; but such activities instigated by man as agriculture, grazing, lumbering, fire and excavations, are retrogressive. Physiographic succession is progressive where detritus is deposited along the flood plains of Devil Creek and Piedra River, and retrogressive where the rains have washed away the vegetation with the soil from the mountain slopes and where arroyos have been formed.

The successional series of plant associations of the mesa

top, hills and slopes and the well-drained upland along streams is xerarch. The only hydrarch succession is that of the slough in the Populus-Salix association bordering the Piedra River. The preponderance of xerophytic associations here indicates young topography. The lithosere seems to predominate in this area. It occurs in greatest prominence in the pinyon-juniper association on top of Chimney Rock Mesa and in the yellow pine and Gutierrezia associations.

The only plant associations which are free from grazing, lumbering, excavation or fire, and hence belong to the primary series, are: the lichen association, portions of the mixed shrub and Pseudotsuga associations on the northwest face of Chimney Rock Mesa where plant growth is dense and the slope is very steep, and a small portion of the Populus-Salix association on Devil Creek near the place where it joins the Piedra River.

Both climatic and physiographic or postclimaxes occur here. The yellow pine association is the climatic climax, while the Pseudotsuga association is here considered the physiographic climax for the conifer forest, and Populus-Salix association for the deciduous forest, for the foothill zone. The pinyon-juniper association is the climax for the upper sonoran zone.

The xerarch succession in both upper sonoran zone and the foothill zone is represented in series of associations by xerophytic lichens, herbs, shrubs and trees. The plant associations are listed in accordance with this concept in the order of succession in which they are believed to occur in the two plant zones.

PLANT ASSOCIATIONS

Upper Sonoran Zone	Foothill Zone
Xerarch succession	Xerarch succession
Lichen	Lichen
<u>Eriogonum</u>	<u>Gutierrezia</u>
Mixed shrub (open stand)	Sagebrush
Pinyon-juniper	Mixed shrub (close stand)
a. Top of mesa	<u>Chrysothamnus</u>
	Yellow pine
	<u>Pseudotsuga</u>
	Hydrarch succession
	<u>Populus-Salix</u>

METHODS OF INVESTIGATION

While the physiognomy and ecological structure of the plant associations were determined primarily by observations when making plant collections over the entire area, the validity of each association was finally established by a quantitative study of the floristic composition. The lichen and Populus-Salix associations were the only ones in which quadrat studies were not made.

Quadrat studies.--In making the quadrat studies the usual size of one meter square was used. The quadrats were marked off with a cloth surveyor's tape divided into meters and decimeters, an eyelet being placed at each meter through which a steel stake was run for fastening the tape to the ground. The quadrat was outlined and then subdivided by placing one meter of tape parallel to and one decimeter from the base of the quadrat so as to cut off a strip 10 decimeters long and one decimeter wide and then studying each square decimeter from left to right.

Both chart and list quadrats were made. For the chart quadrats the plants in each square decimeter were charted upon paper to such a scale that one-half centimeter equalled one decimeter, or five centimeters equalled one meter on the ground. Each plant was indicated on the chart by a given symbol which was either the first letter of the generic name or that and the first or first and second letter of the specific name. In addition to the cross which indicated the plant stem, for shrubs a dotted line was used to outline the spread of the plant as viewed from above.

In the list quadrat a list of the plant species was made along the left side of the paper as the plants were found, the number of each quadrat was given twice across the top of the page and in one column below the number the occurrence of the plant species was marked as "1" and an exponent expressed the number of individuals in that quadrat. In the next column below the same number the total coverage in percent for each plant was given for the quadrat. In the case of grasses which occurred as a solid ground cover as in Bouteloua oligostachya it is not possible to record the number of plants. Coverage of herbs and shrubs was determined from one-half to one inch above the soil surface. Single-stemmed plants were found to average about 10 to 15 plants per square decimeter. Aside from the cover of the stems of the shrubs they doubtless decrease the possible cover of herbs because of light, food, or moisture relationship or any combination of these factors. Soil and rock cover were charted and the percentage of each recorded. Since vegetation is sparse in this region it is regarded as rather an important part of the record. Whenever rocks

are present they will be mentioned under the topic of quadrat studies for each association.

This field data was made into tables in which the plants were listed in the order of their frequency or general distribution throughout the association. When the plant associations were large they were divided into various habitat types. The average percentage of frequency and cover per quadrat was given for each plant and for the total number of quadrats for each habitat and for the entire association. In summarizing the records the total soil, rock, plant cover, and the number of plant species and plants per quadrat were recorded for the total number of quadrats represented. A more careful analysis of the vegetation was made by recording in addition the average number of species and coverage for trees, shrubs, herbs, and grasses per quadrat for each association.

Both transects and scattered quadrats were employed in the study of the association. Which was to be used depended largely upon the topography of the area and extent of the association. The distribution of the quadrats will be discussed under each association.

The number of quadrats studied was not uniform for each association. Where the area of the association was small, the surface similar throughout, and the floristic composition seemed uniform, as in the Gutierrezia and sagebrush associations, only a small number of quadrats, about ten, were chosen. In areas of irregular surface a small number were taken in the various habitats of the association. The quadrats in these varied habitats show clearly the effects of open and protected places, direction and steepness of slope, and soil composition upon the number of plants and the species found.

The complete plant list of 199 genera and 305 species for the area surveyed and the association or associations in which each plant occurs is given at the end of this manuscript.

Raunkaier's law of frequency.--Raunkaier's frequency classes in which the species occurring in less than 1% to 20%, 20% to 40%, 40% to 60%, 60% to 80%, and 80% to 100% of the quadrats were recorded for each association. A, B, C, D, E respectively represent each of these percentage groups. Raunkaier found that the species of least frequency were the most numerous, and that for Europe the frequency declines steadily, then, as the highest frequency is reached, it increases slightly. This he expresses as follows: $A > B > C \approx D < E$. Kenoyer (9) in applying this to studies made in Michigan found that there were on the average more species in class A and fewer in class E than in European averages. He accounts for this by saying that the associations

here are less stabilized. He finds that when the first group is large that the fourth group is larger than the fifth. The results of the studies for the associations in the Chimney Rock area coincide with those of Raunkaier in so far as the species of least frequency being the most numerous is concerned, and with Kenoyer's in that there are more species in group A than in Raunkaier's. Except in the sagebrush association, class E was found to be less than or occasionally equal to class D in the Chimney Rock area, which is not entirely in agreement with the data given in the tables by Kenoyer (9). The results obtained in the Chimney Rock area may be expressed then as follows: $A > B > C \approx D \approx E$.

Coverage.--Because of the small percentage of plant cover in the xerophytic associations studied it was thought that a clearer idea of the distribution of plant cover might be obtained if the percentage of cover were divided into the following five classes: those having a cover of .001% to .01%, .01% to .4%, .4% to 1%, 1% to 10%, and 10% to 20%.

XERARCH SUCCESSION

1. Lichen Association.--The lichen association occurs in two habitats, i.e., upon rocks and soil. It is the pioneer association in the xerarch succession. Lichens were not found upon the masses of exposed rock surfaces of the Chimney Rocks and the steep cliffs bordering Chimney Rock Mesa, probably due to the rapid disintegration of the rocks. Both crustose (c) and foliose (f) lichens were found, the former being most abundant. Lichens were observed to occur rather sparsely upon rocks in the pinyon-juniper association on top of Chimney Rock Mesa, and on the rocks on all slopes of the yellow pine association, and very abundantly on the large rocks of the Gutierrezia association.

Lichens were collected primarily on the rocks in the pinyon-juniper association on top of Chimney Rock Mesa. The following is a list of the species with the type indicated in parentheses collected on the mesa:

<u>Lecidea cyanea</u> (Ach.) T. Fries (c)	<u>Parmelia conspersa</u> (Ehrh.) Ach. (f)
<u>Lecidea latypha</u> Ach. (c)	<u>Staurothele umbrina</u> (Ach.) Tuck. (c)
<u>Lecanora hageni</u> Ach. (c)	<u>Caloplaca elegans</u> (Link) T. Fries. (c)
<u>Pertusaria</u> sp. (c)	

The foliose lichen Peltigera canina Willd. was collected on the soil surface beneath the trees of the Pseudotsuga association.

2. Eriogonum Association.--The Eriogonum association occurs

upon the Lewis shale slides. Observations were made on the habitats of this association on the shale slide to the north and west of the Companion Chimney Rock and the shale slide ridges along the south-facing slope of the canyon running northeast from the Johnson sawmill toward the base of Chimney Rock Mesa. Quadrat studies were made on a ridge in this latter canyon. These ridges interrupt the continuity of the yellow pine association. Pinus edulis was seen along the sharp edge of the ridges and at the top of them to a point where the gray shale and the yellowish-brown soil above them met. On this latter soil the yellow pine grew.

Next to a rock surface the habitat upon which plants established themselves with greatest difficulty is that of the shale slide because of the movement of the small shale particles down the steep slopes. The xerophytic herb stage on this habitat then represents the pioneer stage in the successional series toward the pinyon-juniper climax. Only plants with very long roots can establish themselves here. These pioneer plants establish themselves most slowly on the south- and west-facing slopes where climatic and edaphic conditions were most severe for plant growth. Horizontal lines of plants were often seen where harder strata occurred in the shale beds. Many of the deep rooted herbs found on the shale slides were also growing in the rock crevices or on the very shallow soil covering the rocks on the Chimney Rock Mesa.

The quadrat studies made on the ridge really represent a study in the xerophytic succession of an upper sonoran zone series which consisted of xerophytic herb or Eriogonum association, the mixed shrub association and the pinyon-juniper association. The two latter occurred together here, indicating a teloscoping of the two associations. The 37 quadrats were made at the (1) base, (2) middle and (3) top of the ridge.

(1) The four quadrats at the base of the ridge contained 16 species with a total cover per quadrat of 15.05%. Berberis aquifolium with a cover of .775% and Quercus gambellii with a cover of .025% were the only shrubs. The ten forb species dominated the habitat with a total cover of 12.975%. The most abundant forbes given in their order of frequency and the cover of each were: Lithospermum multiflorum, 4.25%; Eriogonum lonchophyllum, 4%; Artemisia coloradensis, 2.5%; Kuhnia leptophylla, .75%; Pachylophus macroglottis, .75%; Apocynum lividum, .5%; and Tragia ramosa, .1%. The three grasses had a total cover of 1.275% and the order of their frequency and the cover value of each is: Agropyron smithii var. molle 1%, Oryzopsis hymenoides .25% and Sitanion hystrix .025%. The fine soil, the large amount of moisture retained from the run-off from the ridge, and less exposure at the base of the gulch may account for the larger percentage of

plants here than in the other habitats.

(2) The flora at the middle of the slope was most typical of the Eriogonum association and represented the most xerophytic aspect in the succession. In the 16 quadrats 10 species had a total cover of 9.92% per quadrat. Of the two shrubs Purshia tridentata occurred in 24.3% of the quadrats and had a cover of .53%; Rhus trilobata occurred in only one quadrat and had a cover of .905%. The 6 forb species covered 7.8% of the area. Eriogonum lonchophyllum had a frequency of 93.75% and a cover of 6.73%. It is a low-growing, hairy-leaved, suffruticose, deep rooted perennial. The plants next in order of frequency, the highest frequency being 37.5%, together with the cover of each, were: Tragia ramosa .181%, Kuhnia leptophylla .671%, Opuntia fragilis .2%, Allionia linearis .012% and Mirabilis multiflora .0062%. The two xerophytic grasses present were Hilaria jamesii with a frequency of 62.5% and a cover of .347% and Oryzopsis hymenoides with a frequency of 18.7% and a cover of .2%.

(3) The plant cover at the top of the ridge was primarily of trees and shrubs. The total plant cover was 11.28%. Trees formed the dominant cover, which was 7.82%. Pinus edulis, averaging six decimeters in diameter at the ground line, had the largest cover, 5%. Of this amount 1.64% was for the trunk and 3.46% for the roots which were exposed on the surface of the ground; and in places the roots were as much as two decimeters in diameter. Pinus scopulorum, about six and one-half decimeters at the ground line, grew in a depression between two ridges. The total shrub cover of 6 species was 2.41%. Their order of frequency and cover were as follows: Purshia tridentata .897%, Berberis aquifolium .088%, Quercus gambellii .176%, Rhus rydbergii 1.17%, Yucca baccata .0735% and Amelanchier sp. .059%.

In the most xerophytic habitats and where the shale slides were very loose it was observed that Eriogonum lonchophyllum, Asclepiodora decumbens or Brickellia californica in the order given were the only plants represented. Other plants observed to have established themselves independently upon this habitat and which were soil binders were:

Mirabilis multiflora
Yucca baccata
Berberis aquifolium
Rhus rydbergii

Apocynum lividum
Aulospermum Betheli
Chaenactis douglasii
Cirsium pulchellum

Raunkaier's frequency classes are 0-14-1-1-0 for the base, 5-3-0-1-1 for the middle, 12-3-0-0-0 for the top and 25-2-0-1-0 for the entire association. The cover classes are 0-8-7-1-0 for the base, 1-5-3-1-0 for the middle, 0-10-2-3-0 for the top, and 6-16-3-3-0 for the entire association.

3. Gutierrezia Association.--The Gutierrezia association of the foothill zone covers most of the southeast-facing slope of the mountain north of the main highway for about one mile east from the Piedra School at an altitude between 6,450 and 6,600 feet.

The habitat, upon which 10 quadrat studies were made, was on the upper and lower parts of the exposed slope, having a 19.8% rock cover interspersed with a yellowish-brown clay soil. The total plant cover of 22 species was 19.3%. Only herbaceous plants were represented, of which 19 species of forbes formed the major part, covering 14.2% of the area. Artemisia coloradensis, a single stemmed plant, had both the greatest frequency, 90%, and the highest cover, 4.9%. While Gutierrezia sarothrae, from which the association was named, was only second in frequency, and covered 2.4% of the area, it provided the dominant aspect of the association. The plant has numerous erect branches which have rather a wide spread at the top. Other forbes having a cover of .1% or more were Artemisia frigida 1.55%, Tragia ramosa 1%, Erigeron flagellaris 1%, Malvastrum coccineum .9%, Opuntia fragilis .725%, a legume .575%, Chrysopsis bakeri .45%, Sideranthus gracilis .22%, Dysodia papposa .1% and Eriogonum racemosum .1%.

Three grasses occurring with equal frequency covered the remaining 5.1% of the area. These are here given in the order of their percentage of cover per quadrat: Bouteloua oligostachya 2.3%, Aristida fendleriana 1.5% and Bouteloua curtipendula 1.3%.

Raunkaier's frequency classes of this association were 4-9-6-2-1, and the cover classes were 0-10-6-6-0.

4. Sagebrush Association.--Sagebrush, Artemisia tridentata, occurred sparingly in the part of the Chimney Rock area surveyed. A few bushes were seen on the Chimney Rock Mesa in the pinyon-juniper association. The only place where there was an assemblage of shrubs sufficiently large to call it an association was a flat place about 6,600 feet elevation on the southwest-facing hill immediately east of the Piedra School house, where there was a rather deep soil cover which had been carried down from the steep hillside to the east of it. The association occurs between the yellow pine, Gutierrezia, and extremely xerophytic mixed shrub associations.

The entire top of the Stollsteimer Mesa to the southwest of Chimney Rock Mesa is covered with Artemisia tridentata except where it alternates with the Pinus edulis which grows on the rocky ridges.

The habitat is very xerophytic in aspect with a rock cover of 1.3% per quadrat for the ten quadrats studied and a total plant cover of 6.66% for the 19 species. Three low-growing shrub species formed 3.7% of the total plant cover. These are given in the order of their descending frequency with the cover of each: Artemisia

tridentata 2%, Chrysothamnus depressus .8%, Purshia tridentata .9%.

The forbes consisted of 13 species with a total cover of 1.39%. The more frequent ones with their percentage of cover were: Malvastrum coccineum .18%, Gutierrezia sarothrae .46%, Portulaca oleracea .04%, Artemisia frigida .11%, Eriogonum jamesii .3% and Artemisia wrightii .2%.

Three xerophytic grasses formed the major herbaceous cover with a percentage of 1.55%. Bouteloua oligostachya was dominant with a cover of 1.35%, then followed Sitanion hystrix .15% and Aristida fendleriana .05%.

To estimate and interpret the cover of shrubs accurately for large areas would involve some knowledge as to the age, species and growth habit of shrubs. It was found in this association that shrubs differ as to age and species in regard to their cover an inch above the ground. Old specimens were found with enlarged stem bases and roots covering a large ground area. Density and spread of tops, number, size, and length of stems are important factors in determining the amount of herbaceous cover under shrubs. The relationship between the shrubs and number of herbs growing beneath them further involves the factors of light, moisture and food.

The decidedly xerophytic nature of this association is seen in the xerophytic species of all the life forms represented.

Raunkaier's frequency classes for this association are 13-4-1-0-1. The cover classes are 6-9-3-1-0.

5. Mixed Shrub Association.--The mixed shrub association varies in its position. In some places it occurs as a belt between the two life zones, in others it is mixed with or alternates with the association of either zone. Where it occurs in belts Rydberg (16) calls it the "chaparral belt" and places it in the foothill zone. Since Cooper's (3) concept of chaparral as that of a shrub with a "small, thick, heavily cutinized" evergreen leaf is accepted, this term has not been used to define the association. This association was found in three distinct types of habitat, varying from the extremely xerophytic one to a mesophytic one. The most xerophytic habitat occurs on the steep southwest-facing slope east of the Piedra School house. The other two occur on the steep southeast and northwest slopes of the Chimney Rocks and on the same slopes of the Chimney Rock Mesa and its extensions to the south and southwest.

In the habitat near the Piedra School the mixed shrub association lies between the yellow pine, Gutierrezia and sagebrush associations. Opuntia arborescens, Yucca baccata and Fendlera rupicola were the xerophytic shrubs represented here. Except for one specimen of Opuntia arborescens on the extreme southwestern

cliff edge of the Chimney Rock Mesa this is the only place where it was found at all and in abundance.

The next most xerophytic habitat for this association was observed on the south- and east-facing slopes of the Chimney Rock Mesa, where it occurred above the yellow pine association, but alternated with the pinyon-juniper association. The following xerophytic shrubs, which grew in very open stands, were noted: Purshia tridentata, Fendlera rupicola, Cercocarpus montanus, Yucca baccata, and Amelanchier utahensis. A few scattered specimens of these shrubs were seen near the middle and top of the north slope leading to the Mesa.

On the steep north- and west-facing slopes of the north side of Chimney Rock Mesa where the shrubs occurred in a close stand, and as a belt above the yellow pine association and below the pinyon-juniper association on top of the Chimney Rock Mesa the mixed shrub association had its most mesophytic aspect. This steep north slope showed variation in habitat in a vertical direction. Near the base of the slope the soil was deepest and due to the greater distance from the disintegrated rock on the cliffs there were almost no rocks here; there was less light, lower temperature than higher, more moisture, due to position and greater atmospheric humidity. Near the top of the slope the light is intense, the temperature higher, the soil is very shallow, and there is a rock cover of over 6%. Plants near the top of the slope were lower in growth habit, doubtless because of these more xerophytic conditions.

Quadrat studies were made on this slope. The total rock cover per quadrat for the association is 1.25%; the total plant cover 14.718%. The cover of the life forms were: shrubs 10.496%, forbes 1.5% and grasses 2.726%. A more detailed analysis of the floristic composition of the association was made possible by dividing the study into the more xerophytic ridge (a) and the mesophytic gulch (b) habitats. In the ridge study 44 quadrats were made on the (1) northeast and (2) southwest exposures near the base of this north slope at 7,300 feet altitude where the trail to Chimney Rock first becomes very steep, and at the (3) top of the slope where it joins the vertical rock face surrounding the mesa. The gulch study was made below the first extensive close stand of Pseudotsuga on the north slope to the west of the Chimney Rock trail. The nine quadrat studies were made (1) on the base of the gulch and on the (2) northeast and (3) southwest exposures.

a. Ridge.--The total plant cover of 28 species for the ridge near the base of the north-facing slopes is 15.32%, with a predominating shrub cover of 10.62%. Forbes had a cover of 1.76% and grasses and sedges 3.28% per quadrat. The following five

shrubs occur in all three habitats in their order of frequency for the entire association: Quercus gambellii, Amelanchier utahensis, Cercocarpus montanus, Symphoricarpos oreophilus and Fendlera rupicola. Their order of frequency and cover varies with each habitat. In addition to these Physocarpus monogynus and Rhus trilobata occurred at the top of the ridge. Quercus gambellii had the highest frequency in all of the habitats, and this was followed by Cercocarpus montanus and Symphoricarpos oreophilus on the more xerophytic habitats and Amelanchier utahensis on the northeast exposure. Quercus gambellii was second in cover value in all of the habitats. Amelanchier utahensis, occurring on the more mesophytic northeast-facing exposure had the highest cover, 11.12%; Cercocarpus montanus had the highest cover, 2.53%, on the southwest-facing exposure; and Symphoricarpos oreophilus with a cover of 3.25% and Quercus gambellii, 2.08%, had the highest covers for the top of the slope.

In this rather close stand of shrubs it was noticed that the stem cluster of Amelanchier is wide and open at the base but does not spread much at the top. Cercocarpus, on the other hand, had its stems close together at the base with a wide spreading top. It follows the crest of the ridges and its plumose fruit in the fall together with its gray green foliage enable one to distinguish it at great distances. Fendlera rupicola is a coarse-twigged, irregularly shaped shrub with a blossom resembling the apple, and grows in the more xerophytic habitats.

(1) The northeast exposure near the base of the slope has the most mesophytic habitat of the ridge. The 19 species of plants in the 24 quadrats studied had a cover of 20.62%. Shrubs dominated with a cover of 14.02%. Of the 12 forbes which had a cover of 1.98%, the following most abundant ones are given in the order of their frequency, together with the percentage of cover of each: Artemisia coloradensis .32%, Erigeron divergens .208%, Penstemon glabrescens .583%, Actinea leptoclada .146% and Comandra pallida .17%. The difference between the grass and sedge species which together had a cover of 4.635% was not always certain. Their cover is believed to be about 4.41% for Koeleria cristata and 2.25% for Carex heliophila.

(2) Twelve quadrat studies were made on the southwest exposure. The 19 species of plants had a total cover of 9.4%, which may indicate the more xerophytic nature of the habitat. Shrubs dominated with a cover of 5.19%. The same 12 species of forbes with a cover of 1.72% occurred here as on the northeast exposure but the order of frequency and cover differed. They are here given in the order of their frequency with the cover of each: Artemisia coloradensis .525%, Androsace septentrionalis var. diffusa .125%,

Actinea leptoclada .416%, Artemisia dracunculus .158%, Erigeron divergens .15%, Achillea millefolium .125%. The total grass cover of 2.483% was almost entirely occupied by Koeleria cristata with a cover of 2.475%.

(3) The habitat at the top of the north slope was characterized by a rock cover of 6.12% and 12 species of plants, the total cover of which was 10.11%. Here the shrub cover of 8.718% remains the dominant one. There were only 4 species of forbes, the cover of which was .997%. These are given in their order of frequency with the cover of each: Erigeron macranthus .937%, Allionia linearis .086%, Achillea millefolium .05%, Gymnolomia multiflora .01%. The two grasses of equal frequency are given with their cover value: Koeleria cristata .312% and Hilaria jamesii .086%.

b. Gulch.--The gulch habitat, where 9 quadrat studies were made, with its 19 plant species and their cover of 10.2%, stands in sharp contrast floristically to the ridge. Except for Quercus gambellii and Symphoricarpos oreophilus there is no duplication of shrub species with the ridge. The eleven species of shrubs for the dominant cover of 9.76% was recorded. The total herbaceous cover is only .457%. In order to study the effect of slope and exposure the gulch was divided into three habitats: (1) bottom, (2) northeast exposure and (3) southwest exposure.

(1) Four quadrats were studied at the bottom of the gulch. The 14 species occurring here had a total cover of 9.305%, of which 9.115% of the cover was shrubs. The eight shrubs will be given in the order of their frequency together with the cover of each: Quercus gambellii 3.25%, Berberis fendleri 1.27%, Amelanchier bakeri 3.75%, Symphoricarpos oreophilus .52%, Rosa fendleri .175%, Prunus melanocarpa .075%, Pachystima myrsinites .025%, and Berberis aquifolium .05%. The dominant herbs of the 6 species were Smilacina amplexicaulis, Heuchera parvifolia; other herbs were Clematis pseudoalpina, Anemone cylindrica.

(2) The two quadrats on the northeast-facing slope with 11 species and a total plant cover of 18.75% represented the most mesophytic habitat on the north-facing slope of the Mesa. Shrubs dominated with a total cover of 17.675%. The low-growing, evergreen shrub Pachystima myrsinites, regarded as a mesophytic indicator and the most mesophytic shrub in the entire Chimney Rock area, had a total cover of 12.5%. With this shrub are the following together with the cover of each: Quercus gambellii 3.25%, Amelanchier bakeri 1.25%, Prunus melanocarpa .2%, Symphoricarpos oreophilus .2%, Rosa fendleri .15%, and Berberis aquifolium .025%. The herbaceous cover of 1.15% was represented by Clematis pseudoalpina .5%, Smilacina amplexicaulis .5%, Erigeron macranthus .1%

and the rare Lupinus ammophilus .05%.

(3) The southwest-facing slope with 13 species of plants having a total cover of 6.19% was the most xerophytic. Shrubs were dominant with a cover of 6.15%. These are given in the order of their frequency with the total cover per quadrat of each: Quercus gambellii 3.5%, Pachystima myrsinites 1.5%, Rhus trilobata .066%, Amelanchier bakeri .5%, Fendlera rupicola .5%, Prunus melanocarpa .033% and Symphoricarpos oreophilus .033%. Clematis pseudoalpina was the only herb present.

A comparison of the ridge and gulch flora concluded from the quadrat studies showed that the northeast exposure was the most mesophytic and had the greatest plant cover in each habitat. There were more shrub species in the gulch than on the ridge. Quercus gambellii had the greatest frequency of all shrub species in both habitats. Except for Quercus gambellii and Symphoricarpos oreophilus the shrub species on the ridge were different from those in the gulch, those of the ridge being xerophytes while those in the gulch were mesophytes. Forbes had a greater total cover, were more numerous as to species, and consisted of an entirely different list of plants on the ridge than in the gulch. Here, as in the case of shrubs, the species on the ridge were xerophytes while those in the gulch were mesophytes. There were no grasses in the gulch. Of the two grasses found on the ridge Koeleria cristata was the dominant one and found at the base of the slope while Hilaria jamesii was found only at the top of the slope.

The following additional facts regarding the flora were observed from a survey of the entire area. While the oak was the dominant shrub species it occurred in densest stands and as thickets at the base of slopes where the soil was deepest, and was stunted and lower growing on the shallower rocky soils and more exposed slopes. It was continuous from the yellow pine association. Some humus had collected beneath the denser stands of the oak and beneath them mesophytic plants were growing. Symphoricarpos oreophilus was found as an under shrub with the shrubs, but it occurred more abundantly with the oaks.

In the mixed shrub association the plants of the foothill zone are found more characteristically in the more mesophytic habitats on the lower parts of the slopes, whereas the plants representative of the upper sonoran zone are found on the upper slopes and on the more xerophytic south- and east-facing slopes of the mesa.

The mixed shrub association may be considered here as a transition association which has the possibility of taking its place in the successional series leading to three different plant

associations. The following habitats indicate development toward the given associations: the most xerophytic habitats toward the pinyon-juniper associations; the less xerophytic habitats like the ridges of the north-facing slope of the mesa toward the yellow pine association; and the mesophytic gulches of the north-facing slope toward the Pseudotsuga association.

Raunkaer's frequency classes for the ridge are 19-7-0-1-1, for the gulch 5-7-5-1-1 and for the entire association 33-5-0-1-1. The cover classes for the ridge are 7-15-2-4-0, for the gulch 5-7-5-1-1 and for the entire association 13-21-1-5-0.

6. Pinyon-juniper Association.--The pinyon-juniper association is the climax association of the upper sonoran zone and the most xerophytic of the conifer forest associations. It is second only to the yellow pine zone in area covered. The plants comprising it are for the most part typically upper sonoran. The association occurs on the highest part of the Chimney Rock Mesa at an elevation of 7,600 feet and continues along the extension of the mesa to the southeast and southwest. At lower elevations it was found on the ridges and near the top of very loose shale slides. The reasons for its occurrence at this high altitude are discussed under the topic "Vegetative life zones."

In the 74 quadrat studies of the association two distinct habitats were noted: (1) in the open, and (2) under a pinyon tree. The habitat in the open was characterized by flat rocks alternating with about an inch of buff or yellowish-brown clay soil overlying the cap rock. Subsoil and humus appeared to be lacking. This may be accounted for by the low rainfall, very high daily temperatures with wide fluctuations, and winds which cause the oxidation of the plants before they have an opportunity to decay.

Under the pinyon the soil was covered with pine needles and cones, and had a darker brown color, indicating the presence of some humus due to disintegration of the plant growth and needles. The soil immediately under the outer edge of the branches was shallow but increased in depth toward the tree trunk to at least three inches. The deeper soil, less evaporation of moisture from the surface, and a larger humus content under the pinyon than in the open, leave either a difference in chemical content of the soil, or shade, or both of these factors as possible explanations for the difference in floristic composition and the smaller percentage of plant cover under the pinyon than in the open.

Considerable areas of bare cap rock are exposed about the edges of the mesa. In many places the pinyon was seen growing upon the rock faces and in others in the crevices between the bare rocks. The soil at the edges of the mesa is very shallow.

The pinyon-juniper association on Chimney Rock Mesa

conformed to the usual situation encountered at higher altitudes in consisting of an almost pure stand of the pinyon, Pinus edulis with very few scattered specimens of Juniperus utahensis and Juniperus scopulorum. Phoradendron juniperum growing on Juniperus scopulorum, was found at the extreme southwestern extension of the mesa. Except at the end nearest the causeway the trees formed a fairly close stand. At about a foot above the soil surface the trees on the mesa varied from six to twenty inches in diameter and had an estimated height of fifteen to thirty feet. There were no cut trees on the mesa and only a few large trees had fallen from wind or other causes.

The average rock cover for the entire association was 10.84%, the total plant cover 17.67%, of which the grass cover constituted 15.06%, forbes 2.4%, shrubs .206% and trees .24%. The open habitat had an average rock cover of 20.58% and a soil cover of 48.94% per quadrat, whereas under the pinyon there was a rock cover of 4.2% and a soil cover of 82.84%.

(1) A representative assemblage of the flora of the open habitat was secured by selecting quadrats between the trees and at the edge of the mesa. The total plant cover was 30.48%. The eight grass species had a total cover of 20.189%. Grama grass, Bouteloua oligostachya, was the dominant herb in the open having a cover of 19.06%. The other grasses in their order of frequency together with the cover of each are: Agropyron smithii var. palmeri .41%, Aristida fendleriana .01%, Sitanion hystrix .01%, Muhlenbergia montana .53%, Sporobolus cryptandrus .135%, Oryzopsis hymenoides .033%, Oryzopsis micrantha .003%.

The 25 forb species of the open habitat had a total cover of 10.03%, and in their order of frequency the dominant ones with the cover of each were: Opuntia fragilis 6.2%, Eupatorium texense 1.2%, Brickellia californica .966%, Artemisia coloradensis .533%, and Leucelene ericoides .41%. On the narrow causeway and nearer the edge of the cliff where conditions were more xerophytic suffrutescent herbs such as Eupatorium texense and Brickellia californica were dominant.

Typically upper sonoran shrubs listed in the quadrats as occurring most commonly between the pinyons were: Artemisia tridentata, Cercocarpus montanus, Fendlera rupicola, Purshia tridentata, and Chrysothamnus graveolens. Other shrubs usually growing in more mesophytic habitats but here growing at the edge of the cliffs were Prunus melanocarpa, Amelanchier bakeri and Rhus trilobata.

(2) Forty-four quadrats were necessary to make a study of the plants under the pinyon trees. The total plant cover was 12.96%. Of this amount grasses had a cover of 10.82%, forbes

1.61%, shrubs .105% and trees .409%. The following description includes all plants in a vertical line from the end of the branches to the ground and in to the tree. The tree studied was about 40 centimeters in diameter at the ground, and the lower branches had a spread of seven meters and the maximum distance of their tips from the ground was eight to ten decimeters. Many trees had all or a part of their branches touching the ground. Bouteloua oligostachya, with a total cover of 4.1%, except at the southwest side of the tree, occurred as a circle from the outer edge of the branches and in toward the tree trunk not to exceed one meter. Opuntia fragilis with a cover of .227% and Artemisia coloradensis with a cover of .436% were the dominant forbs at the south edge of the branches where the vegetation was very sparse; the former plant, except along the north side of the tree, continued with less frequency about the outer edge of the area under the branches. Leucelene ericoides with a cover of .318% was very abundant and formed an almost pure stand in the quadrats at the southwest edge of the branches. Nearer the tree on the southwest exposure Chenopodium album was the dominant species.

Oryzopsis micrantha was the dominant grass under the pinyon tree, having a cover of 6.32%. It formed a close pure stand from near the tree trunk to about one and one-half meter to the north and northeast. Beyond this it occurred as scattered bunches. Outside of the Oryzopsis and within the outer circle of Bouteloua occurred a circle of fairly widely separated bunches of a glaucous narrow-leaved grass which was thought to be Hilaria jamesii, having a cover of .4%. Since it was not found in flower or in fruit at this particular place its absolute identity was impossible.

All shrub and tree species under this tree were seedlings. Large bushes of Ribes inebrians, however, were seen under other pinyon trees.

Identical species and the same general serial arrangement of major plant species were observed under pinyon and juniper trees over the entire mesa. Very few young pinyon trees were seen on the mesa and these were only about one foot in height.

The Raunkaier frequency classes in the open habitat are 32-3-1-0-1, under the pinyon 14-5-4-1-0, and for the entire association 38-5-1-1-0. The cover classes for the open habitat are 17-12-5-2-1, under the pinyon 8-11-3-2-0, and for the entire association 18-22-3-1-1.

a. Top of mesa.--The highest part of Chimney Rock Mesa is nearest the "Companion Chimney" and this small area is elevated much like an island above the expanded southwestern extension with which it is connected by a narrow causeway only a few feet wide. It is on this part that the Indian ruins were excavated by

Dr. Jeancon in 1921.

The habitat of the undisturbed portion of the top of the mesa has shallower soil cover and is more xerophytic, but otherwise similar to that of the pinyon-juniper association on the expanded portion of the mesa. The presence of a specimen of Pinus edulis and an old gnarled specimen of Juniperus scopulorum determined its position as an association.

The flora upon the loose soil about the ruins differed in some respects from that of the native habitat. This habitat afforded a study in secondary plant succession and it will be of interest to learn how long it will take the native flora to establish itself. A few new native plants had come in since the area was visited in 1924. All plants not recorded on the mesa or on the particular habitat designated in 1924 will be starred. Among the plants occurring on loose soil the following six weeds introduced from Europe or Asia were present:

* <u>Bromus tectorum</u>	<u>Melilotus officinalis</u>
<u>Salsola pestifer</u>	* <u>Verbascum thapsus</u>
<u>Chenopodium album</u>	<u>Tragopogon pratensis</u>
<u>Sisymbrium altissimum</u>	

Bromus tectorum was the most abundant grass seen here in 1931.

Three plants of southwestern distribution were found nowhere in the Chimney Rock area except here. They are Malvastrum elatum, Corydalis montana and Sphaeralcea fendleri. This latter plant is a new record for Colorado.

The following plants were found on the loose soil about the ruins or within them. Some were found on primitive habitats of the surrounding area and indicate how native plants finally reclaim a disturbed area.

<u>Stipa comata</u>	* <u>Brickellia californica</u>
<u>Oryzopsis hymenoides</u>	* <u>Gutierrezia sarothrae</u>
* <u>Bromus ciliatus</u>	<u>Chrysopsis bakeri</u>
* <u>Bromus tectorum</u>	* <u>Solidago trinervata</u>
<u>Sitanion hystrix</u>	<u>Machaeranthera rubricaulis</u>
<u>Corydalis montana</u>	<u>Machaeranthera pulverulenta</u>
* <u>Physocarpus monogynous</u>	* <u>Helianthus scaberrimus</u>
<u>Sphaeralcea fendleri</u>	<u>Verbesina encelioides</u>
<u>Malvastrum elatum</u>	<u>exauriculata</u>
<u>Lappula occidentalis</u>	<u>Artemisia coloradensis</u>
	<u>Artemisia dracunculus</u>
	* <u>Chrysothamnus graveolens</u>

In addition to the foregoing list the following plants were collected on the remainder of the top of the mesa surrounding the excavated ruins.

<u>Hilaria jamesii</u>	<u>Lappula occidentalis</u>
<u>Bouteloua oligostachya</u>	<u>Castilleja integra</u>
<u>Eriogonum jamesii</u>	<u>Penstemon trichander</u>
<u>Allionia linearis</u>	<u>Eupatorium texense</u>
<u>Mirabilis oxybaphoides</u>	<u>Artemisia frigida</u>
<u>Malvastrum coccineum</u>	<u>Leucelene ericoides</u>
<u>Mentzelia albicaulis</u>	<u>Actinea leptoclada</u>
<u>Gilia inconspicua</u>	

The shrubs growing on the rocks at the edge of the cliff, in the rock crevices, and on the shallow soil overlying the rock were:

<u>Quercus gambellii</u>	<u>Prunus melanocarpa</u>
<u>Fendlera rupicola</u>	<u>Symphoricarpos rotundifolia</u>
<u>Cercocarpus montanus</u>	<u>Artemisia tridentata</u>
<u>Amelanchier alnifolia</u>	

Fendlera rupicola was the most abundant shrub in this habitat.

We can only postulate on how the weeds or plants not native to this habitat reached here. They may have been carried by man at the time of excavation of the ruins. Sheep were grazing over the entire mesa in 1924, and hundreds of tourists visited the ruins. Wind and birds may have been other agencies in the dissemination of seeds. Sheep grazed the mesa so closely in 1924 that this may account for the new grasses added to the list in 1931.

7. Yellow Pine Association.--The yellow pine association is the most extensive association of the pine belt in the foothill or yellow pine zone and the climatic climax for this zone. On the north-facing slope of Chimney Rock and its Mesa the upper limit of the rock pine was about 7,100 feet elevation. Here it grew down to the lowest elevation--6,450 feet. This occurrence altitudinally below the pinyon-juniper association is an apparent reversal of the usual order.

Alluvial, residual and colluvial soils were the types most widely represented in this association. The alluvial soils at the base of the gulches supported a more mesophytic plant growth than those on the rocky slopes. The surface of many of the hill tops consisted of large lichen-covered rocks alternating with fine yellowish-brown residual soil which was somewhat deeper than that on top of the Mesa. In other cases the cap rock had weathered away leaving only the exposed slopes with the colluvial deposits.

What determines this association as the climax is the fact that the yellow pine, Pinus scopulorum, grows upon slopes of every angle and direction and on varied types of soils. The oak occurred in equal abundance and on all exposures with the yellow

pine, but because of its different life form it is considered as a subdominant and as such is designated as a layer society. On the whole the stand of yellow pine was open, but in gulches and near the base of north- and east-facing slopes where the soil was fine and deep, and factors favorable to germination of seedlings were found, there was a close stand. Quadrat studies were not made in these closer stands where shade and mulch formed by the needles, together with the large number of pine seedlings, prevented an undergrowth of herbs and shrubs.

The yellow pine is plastic in its habitat requirements and the species of herbs and shrubs vary with changing habitats. For this reason 63 quadrats were distributed in such a manner as to give a representation of the plant species for the entire association, and were located on the following four slopes or exposures.

(1) Five quadrats were plotted at about 7,000 feet altitude along the Chimney Rock trail on the flat northwest-facing hill top just before the last steep ascent to the Mesa. There were no rocks on the surface and the 19 species of plants had a cover of 8.94%. Shrubs had a cover of 1.5%. The dominant shrub of the three species was Quercus vreelandii which was accompanied by Purshia tridentata and Prunus melanocarpa. The 13 species of forbes had a total cover of 6.02%. Wyethia arizonica with a cover of 1.6% and Achillea millefolium with a cover of .34% had the highest frequency. Other species having high cover value were Penstemon glabrescens 1.4%, Erigeron flagellaris .9%, Townsendia glabella .5%, Lotus wrightii .4%, and Actinea leptoclada .4%. Three grasses represent the remaining cover of 1.42%. They are Aristida fendleriana 1%, Hilaria jamesii .22%, and Sitanion hystrix .2%.

(2) The southwest-facing slope near the top of the highest hill between Devil Creek and the base of the steep mesa slope at 7,000 feet altitude was divided into three habitat studies: (1) under yellow pine trees, (2) in the open, and (3) the oak shrub and surrounding growth.

1) Under the yellow pine tree the rock cover was 1.58% and the 16 plant species covered 9.97% per quadrat for the 18 quadrats studied. Quercus gambellii was the most abundant shrub as to frequency, 44.4%, and cover, .755%. Cercocarpus montanus occurred here also. Grasses formed the dominant plant cover, 3.96%. Sitanion hystrix had both the highest frequency and the greatest cover, 1.35%. Other grasses in their order of cover were: Koeleria cristata 1.29%, Poa fendleriana .736%, and Bouteloua curtipendula .583%. The cover of the 8 species of forbes was 2.72%. Actinea leptoclada was the forb of highest frequency and greatest cover, 1.63%. Chrysopsis bakeri was next with a cover

of .53%. Other characteristic forbes were Artemisia wrightii, Psoralea tenuiflora and Eriogonum racemosum.

2) The habitat in the open had the greatest rock cover, 9.84%, and total plant cover, 11.03%. Fifteen species were found in the 13 quadrats studied. The three shrubs which had a total cover of 1.53% were Ribes inebrians, Purshia tridentata and Cercocarpus montanus. Grasses formed the dominant plant cover, 7.43%. Bouteloua curtipendula occurred most frequently and its cover of 6.1% was the highest. In the order of their cover Sitanion hystrix, Aristida fendleriana and Koeleria cristata were the remaining grass species represented. The total cover of 7 species of forbes was 2.07%, and they occurred in the following order of frequency, with the plant cover of each: Actinea leptoclada .66%, Psoralea tenuiflora .63%, and Chrysopsis bakeri .34%. Young plants of Pinus scopulorum from one to nine decimeters in height were growing among the grasses and beneath the outer edge of the branches of Cercocarpus.

3) Eleven quadrats were made about a group of oak shrubs to determine not only the size of the group but the herbaceous growth beneath the oaks. The total number of plant species was nine, with a total cover of 15.5%, the oak shrub occupying 12.8% of it. Five yellow pine seedlings from one to eight decimeters in height with a frequency of 36.3% developed as a circle within the outer edge of the branches of the oak. Four species of grass covered 2.2% of the area. In their order of frequency with the cover of each they were: Sitanion hystrix .58%, Poa fendleriana .9%, Bouteloua curtipendula .68%, and Koeleria cristata .209%. The four forb species with a total cover of .336% were: Chrysopsis bakeri, Actinea leptoclada and Artemisia wrightii.

(3) The east-facing slope was divided into three habitats: (1) the base, (2) slightly above the base, and (3) top. The rock cover varied from none at the base and slightly above to 3% at the top. The average plant cover was 12.9%, with the greatest cover at the base of the slope. Shrubs formed the dominant plant cover with a total of 11.66%. Forbes had a cover of 1.06% and grasses .12%.

1) At the base of the slope the 16 species in the eight quadrats had a cover of 18.8%, which was the greatest for the three habitats. Nine shrub species dominated with a cover of 18.51%. The shrub species in the order of their frequency, together with the cover of each, are given here: Rosa fendleri 2.18%, Symphoricarpos oreophilus 2.28%, Berberis fendleri 6%, Prunus melanocarpa .91%, Amelanchier utahensis .087%, Rhus trilobata 6.88%, Berberis aquifolium .162%, Quercus gambellii .025%, and Ribes inebrians .012%. Erigeron macranthus, Commandra pallida,

and Artemisia coloradensis were the most abundant of the forbes which occupied the remaining surface. There were no grasses.

2) Slightly above the base six quadrats were studied having 15 species in them. The total plant cover was 6.14%, of which 4.6% consisted of shrubs. Of the five shrub species, Quercus gambellii was dominant, with a cover of 2.17%, followed in order of frequency and cover by Berberis fendleri .7%, Rosa fendleri .283%, Crataegus chrysocarpa .28%, and Symphoricarpos oreophilus .033%. The total cover of forbes was 1.88%. The five important ones listed in the order of their frequency followed by their cover value are: Erigeron macranthus .34%, Conioselinum scopulorum .15%, Wyethia arizonica .66%, Anemone cylindrica .35%, and Aster laevis .31%. The sedge, Carex heliophila, had a cover of .25%.

3) A single quadrat at the top of the slope gave a rock cover of 3%, while the plant cover of 7 species was only 4.5%. Three shrub species with a total cover of 3.4% were represented by Ceanothus fendleri, with a 3% cover, Quercus gambellii, and Amelanchier utahensis. The only herbs are given in the descending order of their cover: Draba helleriana .5%, Artemisia coloradensis .2%, Koeleria cristata .2%, and Poa fendleriana .1%.

(4) An open north exposure on the canyon base opposite the preceding east-facing slope along the trail constituted a habitat with no rocks and 10 plant species, all of which were herbs, covering 21.5% of the area. Chrysopsis bakeri and Artemisia wrightii, each with a cover of 7%, were the dominants. The following each had a cover of 2%: Actinea leptoclada, Aster hebecladus and Helianthus scaberrimus. The sedge Carex heliophila also had a cover of 2%.

In summarizing the quadrat data of the yellow pine association, rocks were found to cover only the open habitats of hill tops and the higher parts of the slopes. The greatest percentage of total plant cover occurred on the more mesophytic north exposure of the broad gulch base, and at the base of the east-facing slope. The largest number of shrub species and the greatest cover was at the base of the east-facing slope. Oaks grew on all slopes and types of habitats. Except for the oaks there was a different grouping of shrub species for the southwest-facing slope and hill top habitats, and the more mesophytic east- and north-facing slopes. These will be listed later under the observations for the entire area. The greatest number of forb species grew on the broad gulch base where the cover was 23.5%, and on the northwest exposure of the flat hill top where the cover was 6.02%. The dominant species so far as the cover in these habitats is concerned were Chrysopsis bakeri, Artemisia wrightii, and Actinea leptoclada

for the gulch habitat and Wyethia arizonica and Penstemon glabrescens for the northwest-facing hilltop habitat.

Grasses had their greatest expression as to number of species and cover, 7.43%, in the open habitat of the southwest-facing slope. Here Bouteloua curtispindula was dominant as to percentage of cover, 6.1%, with Sitanion hystrix, Poa fendleriana, Aristida fendleriana, and Koeleria cristata following in order of dominance.

From these data it is concluded that shrubs dominated the more mesophytic habitats, and grasses the most xerophytic habitats.

In the canyons which lead northeast from Johnson's sawmill on the Piedra River to the base of Chimney Rock and its Mesa, the yellow pine was in its virgin condition in June 1924. By September all the mature trees had been cut and the branches scattered. Since this area is in the National Forest the trees were cut and cared for according to forestry regulations. The mature trees were from eighteen inches to three and one-half feet in diameter and 100 to 150 feet high. They were straight and free from branches to within a short distance from the top. Two hundred and ninety-eight annual rings of growth were counted on a stump that was three and one-half feet in diameter at two and one-half feet above the ground.

All the trees between the D. D. Pargin ranch and this National Forest boundary had been cut in previous years (Fig. 3). The stumps of small size trees and the clean cutting indicate that forestry methods had not been used here. The retrogressive effect upon the vegetation of this unscientific method of cutting was noticeable, particularly upon the south- and west-facing slopes of some canyons where there was little if any reproduction of the yellow pines. In these xerophytic cut over habitats only the presence of numerous loose stones prevented excessive washing away of the soil. With no humus and very little available soil water only the most xerophytic herbs, such as Yucca glauca, Gymnolomia multiflora and Aristida fendleriana were the first to establish themselves. These plants were followed by such xerophytic shrubs as Purshia tridentata, Cercocarpus montanus, Ceanothus fendleri and oaks. Under these shrubs the pine seeds had their first opportunity to germinate. Vestal (20) speaks of the rather abundant occurrence of Ceanothus fendleri beneath the pines in the northern Rockies and its importance as a place for the germination of pine seedlings. This shrub does not occur very abundantly in the Chimney Rock region. These shrubs were the ones that constituted the list for the undisturbed as well as disturbed xerophytic south- and west-facing slopes.

In 1931 the number of young pine trees that were developing

indicated that in the region of the National Forest cutting of mature trees had not interfered greatly with the reproduction of the forest.

Reproduction of the yellow pine was abundant on the east- and north-facing slopes, and especially at the base of areas that were and were not cut over. Where there was considerable shade Pseudotsuga seedlings were present in the undergrowth. On the drier slopes oaks seemed more abundant and taller near the base of the slopes.

At the base of the more protected slopes, such as the east-facing slope, occurred mesophytic shrubs of the gulch type growing upon alluvial soils. Some of these were Rhus trilobata, Berberis fendleri, Rosa fendleri, Prunus melanocarpa and Symphoricarpos oreophilus. Berberis fendleri occurred often in groups upon transported soil in the more mesophytic habitats of the yellow pine, Chrysothamnus and Populus-Salix associations. Where the groups were sufficiently large they were called group societies. Symphoricarpos oreophilus occurred as an undergrowth in xerophytic habitats, but it was more abundant and the leaves were thinner where conditions were more mesophytic.

In the open between oaks and pines, grasses and forbes appeared almost equal. As in the pinyon-juniper association Opuntia fragilis was quite abundant in the more exposed positions. Juniperus scopulorum was rather infrequent in the more xerophytic habitats, but occurred more abundantly associated with the yellow pine in the base of the gulch along the trail leading from the Chimney Rocks.

Raunkaier's frequency classes were as follows: for the top of the hill on the northwest-facing slope 9-7-2-1-0, for top of the hill on the southwest-facing slope 11-7-2-2-0, and for the east-facing slope 21-3-4-1-0, and for the entire association 49-8-1-0-0. The cover classes were as follows: for the top of the hill on the northwest-facing slope 0-13-3-3-0, for the top of the hill on the southwest-facing slope 5-12-2-3-0, and for the east-facing slope 5-18-1-5-0, and for the entire association 16-34-6-2-0.

8. Chrysothamnus Association.--The Chrysothamnus association forms an important shrub association in many parts of Colorado, and it is second only to the sagebrush association in rank. While scattered specimens of Chrysothamnus were found throughout the area, and especially on the top of Chimney Rock Mesa, there were only two places where it grew in sufficient abundance to call it an association.

Quadrat studies were made in both (1) xerophytic and (2) mesophytic habitat types. The xerophytic habitat studied was

on a southwest exposure along the highway on the well drained terrace bordering the north side of Devil Creek between the base of the hill and the Populus-Salix association. A xerophytic type was also observed on a deep alluvial soil south of the point where Devil Creek flows into the Piedra River. Here again it occurred between the Populus-Salix association and the steep slope to the east. The mesophytic habitat studied was on the broad gulch base where the Chimney Rock trail leaves the road going south from Devil Creek along the intermittent stream channel which leads from the steep base of the Chimney Rocks.

The association on the xerophytic habitat seems to be a primary one, whereas there is evidence that the association in the gulch is a secondary one caused partly by the cutting of the yellow pines many years ago. In this latter habitat there was evidence of the fresh deposition of a considerable quantity of soil which was washed down from the steep slopes of the Chimney Rocks.

(1) The 20 quadrats made in the xerophytic habitat of the association had an average rock cover of 1.25% and the 21 plant species had a total cover per quadrat of 9.66%. Only two shrub species were present. Chrysothamnus graveolens with a cover of 3.85% and Rhus trilobata with a cover of .005% formed the dominant aspect of the association.

The eighteen species of xerophytic forbes had the greatest cover value, 5.42%. Of these species only three were found in the mesophytic habitat. They were Eriogonum racemosum, Lotus wrightii, and Artemisia coloradensis. Eight forbes of highest frequency will be given in the order of that frequency together with the cover of each: Dysodia papposa 1.15%, Portulaca oleracea .17%, Kuhnia leptophylla .487%, Pachylophus macroglottis 1.99%, Gutierrezia sarothrae .375%, Asclepias galioides .977%, Eriogonum racemosum .08%, Artemisia coloradensis .04%. Dysodia papposa occurred in 95% of the quadrats, Portulaca oleracea in 65% and the others occurred in 20% to 45% of them. Bouteloua oligostachya was the only grass represented. It had a cover of .38%.

(2) In the ten quadrats studied in the mesophytic habitat the total cover of the 28 species was 8.42%. Shrub species were three times as many as in the xerophytic habitat and they were the dominant life form with a total cover of 4.51%. Chrysothamnus speciosus had a frequency of 90% and a cover of 2.3%. All the other shrubs had a frequency of less than 30% and are here listed in the order of their frequency with the cover of each: Quercus gambellii .06%, Berberis aquifolium .9%, Rosa fendleri .4%, Cornus stolonifera .7%, and Symphoricarpos oreophilus .15%.

The nineteen species of forbes had a total cover of 3.55%.

Clematis scottii had the highest frequency, 80%, and cover, 1.75%. Two plants of 60% frequency were Senecio mutabilis and Geranium atropurpureum, with a cover of .65% and .09%. Other plants with frequencies of 10% to 30% having the higher cover values were Erigeron flagellaris .45%, Clematis ligusticifolia .2%, Chrysopsis bakeri .17%, and Artemisia coloradensis .1%. The species of grasses and sedge present, together with their cover are Bromus porteri .31%, Agropyron tenerum .01%, and Carex heliophila .02%.

The mesophytic habitat provided a place for the development of pine seedlings, which indicated that this association is a part of the succession toward the yellow pine climax and that the mesophytic habitat represents the transition stage between the two associations.

On either side of the highway in the xerophytic habitat where quadrat studies were made were observed group societies (Fig. 1) of Rhus trilobata, Verbesina encelioides var. exauriculata, Mentzelia rusbyi, Asclepias galioides and Salvia pitcheri. Dysodia papposa was the most abundant forb accompanying these dominant plants in each society.

Because of the fewness of shrub species the physiognomy of the xerophytic habitat was more uniform than that of the mesophytic habitat.

Raunkaier's frequency classes for the xerophytic habitat were 13-5-1-1-1, for the mesophytic habitat 21-2-2-1-1, and for the entire association 38-6-1-1-0. Cover classes for the xerophytic habitat were 7-9-2-3-0, for the mesophytic habitat 9-12-4-2-0, and for the entire association 21-20-3-2-0.

9. Pseudotsuga Association.--The Pseudotsuga association occurs north of the Mesa primarily on the north- and east-facing slopes of the "pine belt" of the foothill zone, alternating with yellow pine up to an altitude of 7,100 feet. From 7,100 to 7,600 feet for half a mile on either side of the trail on the north-facing slope of the Chimney Rock Mesa Pseudotsuga either formed pure stands and thereby alternated with the mixed shrub association or it was mixed with these shrubs on the more exposed parts of the slope. For almost the entire length of the sawmill canyon Pseudotsuga was coming in with the yellow pine near the base of the north-facing slopes. This mixture of the trees of the two associations indicated the progress of the succession from the more xerophytic climatic climax of the yellow pine to the more mesophytic physiographic climax of the Pseudotsuga association.

Twenty-four quadrat studies were made as a transect two meters wide from the base of the rock cliff down into a pure stand of mature Pseudotsuga trees on the north-facing slope of Chimney Rock Mesa at the westernmost point of the 7,400 foot contour of

the Mesa top. The studies were divided into two habitat types: (1) that from the cliff base to the edge of the branches of Pseudotsuga trees, and (2) beneath the Pseudotsuga trees.

(1) The habitat from the cliff base to the trees was characterized by slide rock, of which only 6.91% was exposed, and a slope with a 70° angle. The surface with its shallow cover of humus and recently dropped leaves and some moss, together with the shade cast by the cliff in the morning and that cast by the large trees in the afternoon, gave this habitat a decidedly mesophytic aspect. The total plant cover for this habitat was 9.18% with shrubs dominating it with a cover of 8.4%. The four shrubs present in their order of frequency and the cover of each were: Quercus gambellii 1.38%, Symphoricarpos oreophilus .08%, Amelanchier bakeri 4.75%, and Acer glabrum 2.17%.

Forbes, including the moss, had a cover of only .71%. The mesophyte Clematis pseudoalpina dominated in frequency, 41.66%, and cover, .275%. The other forbes were Smilacina stellata and Heuchera parvifolia. The identity of the one grass was not certain, but it resembled Koeleria cristata and had a cover of only .083%. Seedlings of Pseudotsuga were found only in this habitat. These seedlings were about one foot in height.

(2) Beneath the Pseudotsuga trees the shade was greater than under the shrubs; the ground had a loose cover of humus; and the vegetation, except for occasional specimens of the foliose lichen Peltigera canina, and a few tall shrubs with very few branches and thin leaves, and a few herbs, was exceedingly sparse. The trees of Pseudotsuga here were about six decimeters in diameter at the ground line. This close stand of trees was probably able to develop in this position because of the water provided by the snows which lie on the north and east slopes of the Mesa until late spring. The following shrubs occurred in the order of their frequency and the cover is given for each: Quercus gambellii .8%, Symphoricarpos oreophilus .075%, Amelanchier bakeri 2.37%. Farther down the slope Prunus melanocarpa was seen. The only herbs present were Clematis pseudoalpina with a cover of .016% and Smilacina stellata and Heuchera parvifolia, each covering only .0083%. One large tree of Abies concolor was found in this habitat.

Where Pseudotsuga was observed below the close stand in the gulch it appeared as a transition stage with the mixed shrub association. Conditions were quite mesophytic here and with the Pseudotsuga seedlings of various ages occurred the low, evergreen shrub Pachystima myrsinites which have the appearance of being the dominant shrub in the undergrowth.

At the head of the first gulch south of the Johnson saw-mill, running almost east and west leading to Chimney Rock Mesa,

and where it was very narrow and the sides steep, was found the most mesophytic habitat in the area. Lichens and mosses in considerable abundance indicated a moist habitat early in the season. The shade here was very dense, in fact very little sun fell upon the plants at the base of the canyon. Pseudotsuga was reproducing abundantly on both the north- and south-facing slopes. The contrast of the effect upon various plants of the same species growing upon the more exposed slopes above with those down in the canyon was striking. Brickellia californica on top of the Mesa and on the shale slides was only one foot high, whereas here it was four feet high and the leaves were much larger and thinner. At the base of the canyon were shrubs typical of the canyon forest and Populus-Salix association. Here were growing Populus angustifolia, Cornus stolonifera, Rhus trilobata, Acer glabrum, Prunus melanocarpa, and Shepherdia argentea.

Raunkaier's frequency classes for the cliff base were 5-1-2-1-1, for beneath Pseudotsuga 4-0-1-2-0, and for the entire association 6-1-1-1-1. The cover classes for the cliff base were 1-5-1-3-0, for beneath Pseudotsuga 2-2-1-2-0, and for the entire association 1-5-0-4-0.

HYDRARCH SUCCESSION

10. Populus-Salix Association.--The Populus-Salix association had its best expression along the Piedra River and Devil Creek. A few of the more xerophytic species of the association grew in the drier and narrower canyon bottoms between these two streams and Chimney Rocks.

The Piedra River is a rapidly flowing stream and there is little fine material deposited in its bed, which is composed mostly of rounded boulders. These facts explain the absence of plants in the stream bed. At the northernmost part of the area studied the river channel was narrow, but just above where Devil Creek joins it, the flood plain broadens and the stream meanders over a flood plain. Terraces border either side of the river. The deposited soil along the river is for the most part sandy.

The terraces along Devil Creek are higher and better drained on the whole than those along Piedra River. These terraces are not entirely formed by erosion of Devil Creek itself, but are formed largely by the deposit of alluvial soil from the lateral streams flowing into it, or by soil brought down by runoff during torrential rains. It was on the terrace near the road east of the point where the stream bed from the Chimney Rocks joins Devil Creek that the new species, Grindelia exilifolia A. Nels., was collected. The bottom of Devil Creek is for the

most part covered with rounded boulders. Upon these is a dense growth of algae, which was no doubt made possible by the slow movement of the water in the stream. In places along the side of the stream is a deposit of fine soil.

Both xerarch and hydrarch plant successions (Fig. 1) were represented in the Populus-Salix association. The xerarch successional series was seen on the higher terraces where the soil was loose, deep, and well drained. Populus was more abundant in these habitats than Salix. The habitats on the whole were more open and hence had more xerophytic plants growing upon them. Berberis fendleri formed group societies in this association along Devil Creek. The hydrarch successional series consisted of two types of habitat: (1) those plants that immediately bordered the stream; (2) those plants that grew in the slough or poorly drained swamp. The plants which most abundantly bordered the stream were Salix spp., Shepherdia argentea and Populus angustifolia. Alnus tenuifolia, which is seen more frequently at higher elevations, was found here also. Salix spp. formed the canopy and was the dominant plant in the poorly drained habitat which was represented only by a small area southwest of the Pargin house along the Piedra River (Fig. 1). It was here that the only record was kept of the plants as they occurred in the hydrarch succession from the hydrophytic to the most mesophytic habitats. The plants in the remaining habitats were not separated according to xerarch or hydrarch successional series to which they belong.

The plants of this association reached the highest degree of mesophytism, and there were more species than in any association studied. Fleshy fruits were more in evidence here than elsewhere. No quadrat studies were made in this association.

Plants of the Populus-Salix association

Plants of the hydrarch succession growing about the slough in the area southwest of the Pargin ranch house.

Habitats

In water

Typha latifolia (L.)
Alopecurus aristulatus Michx.
Carex rostrata Stokes
Lemna minor L.
Polygonum persicaria L.
Ranunculus Macounii Brit.

Ranunculus Purshii Rich.
Ranunculus scleratus L.
Cicuta occidentalis Greene
Veronica americana Schwein
Mimulus sp.
Galium trifidum L.

Herbs between willows and on hummocks about them

Herbs

<u>Equisetum arvense</u> L.	<u>Epilobium adenocaulon</u> Haussk.
<u>Habenaria hyperborea</u> (L.) R. Br.	<u>Sanicula marilandica</u> L.
<u>Agropyron tenerum</u> Vasey	<u>Pseudocymopterus montanus</u>
<u>Juncus brunescens</u> Rydb.	(Gray) C. & R.
<u>Scirpus atrovirens</u> Muhl.	<u>Conioselinum scopulorum</u> (Gray)
<u>Anemone cylindrica</u> Gray	C. & R.
<u>Ranunculus pennsylvanicus</u> L.	<u>Osmorhiza obtusa</u> (C. & R.)
<u>Ranunculus Macounii</u> Brit.	Fernald
<u>Geum strictum</u> Ait.	<u>Gentiana plebeja</u> Cham.
<u>Thermopsis montana</u> Nutt.	<u>Castilleja septentrionalis</u>
<u>Vicia americana</u> Muhl.	(Lindl.)
<u>Geranium Richardsonii</u> F. & T.	<u>Galium triflorum</u> Michx.
<u>Linum Lewisii</u> Pursh.	<u>Valeriana furfurascens</u> A. Nels.
<u>Sidalcea candida</u> Gray	<u>Campanula rotundifolia</u> L.
<u>Hypericum formosum</u> H.B.K.	<u>Erigeron philadelphicus</u> L.
	<u>Prenanthes racemosus</u> Michx.

Vines

<u>Humulus lupulus</u> L.	<u>Clematis ligusticifolia</u> Nutt.
---------------------------	--------------------------------------

Willows and associated shrubs

<u>Salix amygdaloides</u> Anders.	<u>Crataegus rivularis</u> Nutt.
<u>Salix exigua stenophylla</u> Rydb.	<u>Shepherdia argentea</u> Nutt.
<u>Salix pseudomonticola</u> Ball	<u>Cornus stolonifera</u> Michx.
<u>Salix lasiandra</u> Bentham	<u>Symphoricarpos oreophilus</u> Gray
<u>Salix bebbiana perrostrata</u> (Rydb.)	<u>Lonicera involucrata</u> Banks
Schneider	
<u>Rosa fendleri</u> Crepin	
<u>Crataegus chrysocarpa</u> Ashe	

Additional plants including xerarch and hydrarch successions are given in the plant list. When the specimen of Salix pseudomonticola was collected in 1924 Dr. C. R. Ball stated that he thought it had "never before been collected south of Yellowstone Park."

TABLE II

PLANT LIST AND ASSOCIATION OR ASSOCIATIONS IN WHICH EACH
PLANT OCCURS

Plant List	Plant Associations*										
	1	2	3	4	5	6	6a	7	8	9	10
Thallophytes											
Lecideaceae											
Lecidea cyanea (Ach.) T. Fries	x					x					
Lecidea latypha Ach.	x					x					
Peltigeraceae											
Peltigera canina Willd.										x	
Lecanoraceae											
Lecanora hageni Ach.	x					x					
Pertusariaceae											
Pertusaria sp.	x					x					
Farmeliaceae											
Farmelia conspersa (Ehrh.) Ach.	x					x					
Endocarpaceae											
Staurothele umbrina (Ach.) Tuck.	x					x					
Caloplacaceae											
Caloplaca elegans (Link) T. Fries	x					x					
Pteridophytes											
Polypodiaceae											
Pteridium aquilinum (L.) Kuhn.										x	
Equisetaceae											
Equisetum arvense L.											x
Gymnosperms											
Pinaceae			x								
Pinus edulis Engelm		x				x					
Pinus scopulorum (Engelm.) Lemmon.								x	x		
Pseudotsuga taxifolia (Poir.) Brit.										x	
Abies concolor Lindl.										x	
Juniperus monosperma (Engelm.) Sarg.						x					
Juniperus utahensis (Engelm.) Lemm.						x					
Juniperus scopulorum Sarg						x			x	x	
Angiosperms											
Typhaceae											
Typha latifolia L.											x
Gramineae											
Hilaria jamesii (Torr.) Benth.		x				x	x	x		x	
Echinochloa crus-galli (L.) Beauv.											x
Muhlenbergia montana (Nutt.) Hitchc.						x			x		
Muhlenbergia racemosa (Michx.) B.S.P.									x		
Muhlenbergia wrightii Vasey									x		
Sporobolus cryptandrus (Torr.) Gray						x					
Aristida fendleriana Steud.			x	x		x			x		
Aristida purpurea Nutt.									x		
Stipa comata T. & R.								x			
Stipa vaseyi Scribn.											
Oryzopsis hymenoides (R. & S.) Ricker.									x		x
Oryzopsis micrantha (T. & R.) Thurb.											x

*The plant associations as indicated by numbers are: 1, Lichen;
2, Eriogonum; 3, Gutierrezia; 4, Sagebrush; 5, Mixed Shrub; 6, Pinon-juniper;
6a, Pinon-juniper-top-of-mesa; 7, Chrysothamnus; 8, Yellow Pine; 9, Pseudotsuga;
10, Populus-Salix

[illegible]

TABLE II (Continued)

[illegible]

TABLE II (Continued)

<i>Ribes inebrians</i> Lindl.					X			X	X
<i>Ribes aureum</i> Pursh									X
Rosaceae									
<i>Cercocarpus montanus</i> Raf.					X	X	X		
<i>Purshia tridentata</i> DC.	X		X	X	X			X	
<i>Physocarpus monogynus</i> (Torr.) A. Nels.				X					
<i>Rubus melanolasius</i> Focke									X
<i>Fragaria bracteata</i> Heller ?								X	X
<i>Potentilla fruticosa</i> L.									X
<i>Potentilla propinqua</i> Rydb.								X	
<i>Potentilla orinита</i> Gray							X		
<i>Potentilla gracilis</i> Dougl.								X	X
<i>Geum strictum</i> Ait.									X
<i>Sieversia ciliata</i> G. Don.								X	
<i>Rosa neomexicana</i> Ckll.									X
<i>Rosa fendleri</i> Crepin					X			X	X
<i>Rosa macounii</i> Greene ?									X
Pomaceae									
<i>Amelanchier alnifolia</i> Nutt.							X		
<i>Amelanchier bakeri</i> Greene					X	X			X
<i>Amelanchier utahensis</i> Koehne.	X				X			X	
<i>Amelanchier florida</i> Lindl.									X
<i>Crataegus rivularis</i> Nutt.									X
<i>Crataegus succulenta</i> Schrad.									X
<i>Crataegus chrysocarpa</i> Ashe.								X	X
<i>Peraphyllum ramosissimum</i> Nutt.									X
Drupaceae									
<i>Prunus melanocarpa</i> (A. Nels.) Rydb.					X	X	X	X	X
Leguminosae									
<i>Thermopsis montana</i> Nutt.									X
<i>Lupinus kingii</i> S. Wats.								X	
<i>Lupinus bakeri</i> Greene									X
<i>Lupinus ammophilus</i> Greene					X			X	X
<i>Lotus wrightii</i> (Gray) Greene				X	X			X	X
<i>Melilotus officinalis</i> (L.) Lam.							X	X	X
<i>Melilotus alba</i> Desv.									X
<i>Medicago sativa</i> L.									X
<i>Astragalus hypoglottis</i> L.									X
<i>Astragalus flexuosus</i> (Hook.?) Dougl.						X			
<i>Astragalus proximus</i> Rydb.								X	
<i>Astragalus lonchocarpus</i> Torr.								X	
<i>Glycyrrhiza lepidota</i> Pursh						X		X	X
<i>Psoralea tenuiflora</i> Pursh				X				X	
<i>Vicia americana</i> Muhl.					X			X	X
<i>Lathyrus leucanthus</i> Rydb.									X
Geraniaceae									
<i>Geranium bicknellii</i> Britton									X
<i>Geranium richardsonii</i> F. & T.									X
<i>Geranium nervosum</i> Rydb.									X
<i>Geranium atropurpureum</i> Heller.								X	X
Oxalidaceae									
<i>Oxalis stricta</i> L.				X					
Linaceae									
<i>Linum lewisii</i> Pursh								X	X
<i>Linum australe</i> Heller									X
Euphorbiaceae									
<i>Tragia ramosa</i> Torr.	X	X			X				

TABLE II (Continued)

Euphorbia robusta (Engelm.) Small								X		X
Anacardiaceae										
Rhus rydbergii Small	X									X
Rhus trilobata Nutt.	X		X	X				X	X	X
Celastraceae										
Pachystima myrsinites Raf.				X						X
Aceraceae										
Acer glabrum Torr.				X						X
Acer negundo var. interior (Britton) Sarg.										X
Rhamnaceae										
Ceanothus fendleri Gray									X	
Malvaceae										
Sidalcea candida Gray										X
Sidalcea neo-mexicana Gray										X
Malvastrum elatum (Baker) A. Nels.								X		
Malvastrum coccineum (Pursh) Gray			X	X				X	X	X
Sphaeralcea fendleri Gray								X		
Hypericaceae										
Hypericum formosum HBK										X
Violaceae										
Viola sp.										X
Loasaceae										
Mentzelia multiflora (Nutt.) Gray	X								X	
Mentzelia laciniata Rydb.	X									
Mentzelia rustyi Wooton									X	
Mentzelia albicaulis Dougl.								X		
Cactaceae										
Echinocactus simpsonii Engelm.								X		
Opuntia comanchica Engelm.	X							X		
Opuntia fragilis (Nutt.) Haw.	X	X	X					X	X	
Opuntia arborescens Engelm.								X		
Elaeagnaceae										
Shepherdia argentea Nutt.										X
Onagraceae										
Epilobium paniculatum Nutt.		X	X		X			X		X
Epilobium adenocaulon Haussk.										X
Anogra violacea A. Nels.										X
Anogra coronopifolia (T.&G.) Brit.								X		
Pachylophus macroglottis Rydb.	X							X	X	X
Umbelliferae										
Sanicula marilandica L.										X
Osmorhiza obtusa (C. & R.) Fernald										X
Cicuta occidentalis Greene										X
Ligusticum porteri C. & R.							X		X	X
Conioselinum scopulorum (Gray) C. & R.							X		X	X
Aulospermum betheli Osterh.	X						X			
Pseudocymopterus montanus (Gray) C. & R.							X		X	X
Heraclium lanatum Michx.										X
Cornaceae										
Cornus stolonifera Michx.								X	X	X
Monotropaceae										
Pterospora andromedea Nutt.									X	
Primulaceae										
Androsace septentrionalis var diffusa (Gray) Knuth.			X	X					X	

Asclepiadaceae												
Asclepias speciosa Torr.						.	.	.	.	.	X	X
Asclepias galioides H.B.K.						.	.	.	.	.	X	
Asclepiodora decumbens (Nutt.) Gray						.	.	.	.	.		
Polemoniaceae							X		X			
Gilia micrantha (Kell.) A. Nels.						.	.	.	.	.	X	X
Gilia inconspicua Dougl.						.	.	.	.	.	X	X
Gilia aggregata (Pursh.) Spreng.						.	.	.	.	.		
Polemonium foliosissimum Gray						.	.	.	.	.	X	X
Boraginaceae												
Lappula occidentalis (Wats.) Greene						.	.	.	.	.	X	X
Oreocarya bakeri Greene						.	.	.	.	.	X	
Oreocarya multicaulis (Torr.) Greene						.	.	.	.	.	X	
Mertensia pratensis Heller						.	.	.	.	.		X
Lithospermum multiflorum Torr.						.	.	.	.	.	X	X
Verbenaceae							X				X	X
Verbena medougallii Heller						.	.	.	.	.	X	
Labiatae												
Mentha canadensis L.						.	.	.	.	.	X	
Marrubium vulgare L.						.	.	.	.	.	X	
Dracocephalum parviflorum Nutt.						.	.	.	.	.	X	
Salvia pitcheri Torr.						.	.	.	.	.	X	
Monarda menthaefolia Graham						.	.	.	.	.		X
Hedeoma drummondii Benth.						.	.	.	.	.	X	
Solanaceae												
Physalis fendleri Gray						.	.	.	.	.	X	
Lycium pallidum Miers						.	.	.	.	.		
Solanum jamesii Torr.						.	.	.	.	.	X	
Scrophulariaceae												
Verbascum thapsus L.						.	.	.	.	.	X	X
Scrophularia occidentalis Rydb.						.	.	.	.	.		X
Penstemon trichander Gray						.	.	.	.	.	X	
Penstemon strictus Benth.						.	.	.	.	.		X
Penstemon angustus Pennell						.	.	.	.	.	X	
Penstemon glabrescens Pennell						.	.	.	.	.	X	
Veronica americana Schwein						.	.	.	.	.		X
Mimulus sp.						.	.	.	.	.		X
Castilleja linariaefolia Benth.						.	.	.	.	.	X	X
Castilleja integra Gray						.	.	.	.	.	X	X
Castilleja septentrionalis Lindl.						.	.	.	.	.		X
Orthocarpus luteus Nutt.						.	.	.	.	.		X
Orthocarpus purpureo-albus Gray						.	.	.	.	.	X	
Plantaginaceae							X		X			
Plantago purshii Roem. & Schult.						.	.	.	.	.	X	
Rubiaceae												
Galium boreale L.						.	.	.	.	.	X	X
Galium triflorum Michx.						.	.	.	.	.		X
Galium trifidum L.						.	.	.	.	.		X
Caprifoliaceae							X	X	X			
Symphoricarpos rotundifolius Gray						.	.	.	.	.	X	
Symphoricarpos oreophilus Gray						.	.	.	.	.	X	X
Lonicera involucrata Banks.						.	.	.	.	.		X
Valerianaceae												
Valeriana furfurascens A. Nels.						.	.	.	.	.		X
Campanulaceae												
Campanula rotundifolia L.						.	.	.	.	.	X	X
Compositae												
Eupatorium texense (T. & G.) Rydb.						.	.	.	.	.	X	X

<i>Kuhnia leptophylla</i> Scheele	x			x		x	
<i>Brickellia californica</i> (T. & G.) Gray	x			x	x		x
<i>Brickellia brachyphylla</i> Gray				x			
<i>Gutierrezia sarothrae</i> (Pursh) B. & R.		x	x	x	x	x	
<i>Grindelia exilifolia</i> A. Nels. n. sp.							x
<i>Chrysopsis bakeri</i> Greene		x	x	x	x	x	x
<i>Chrysothamnus depressus</i> Nutt.			x				x
<i>Chrysothamnus graveolens</i> (Nutt.) Greene				x	x	x	x
<i>Chrysothamnus speciosus</i> Nutt.						x	
<i>Sideranthus gracilis</i> (Nutt.) Rydb.		x				x	
<i>Fyrocoma crocea</i> (Gray) Greene							x
<i>Solidago canadensis</i> L.							x
<i>Solidago pulcherrima</i> A. Nels.							
<i>Solidago trinervata</i> Greene					x		x
<i>Townsendia glabella</i> Gray							x
<i>Aster glaucous</i> T. & G.							x
<i>Aster multiflorus</i> Ait.							x
<i>Aster hebecladus</i> DC.						x	x
<i>Aster laevis</i> L.						x	x
<i>Aster caeruleus</i> DC.							x
<i>Machaeranthera rubricaulis</i> Rydb.						x	x
<i>Machaeranthera pulverulenta</i> (Nutt.) Greene						x	x
<i>Leucelene ericoides</i> (Torr.) Greene					x	x	x
<i>Erigeron canadensis</i> L.							x
<i>Erigeron divergens</i> T. & G.					x	x	x
<i>Erigeron flagellaris</i> Gray		x					x
<i>Erigeron philadelphicus</i> L.							x
<i>Erigeron macranthus</i> Nutt.					x		x
<i>Antennaria aprica</i> Greene							x
<i>Gnaphalium strictum</i> Gray					x		x
<i>Gymnoloma multiflora</i> (Nutt.) B. & H.		x			x		x
<i>Ratibida columnaris pulcherrima</i> (DC.) D. Don.							x
<i>Rudbeckia laciniata</i> L.							x
<i>Wyethia arizonica</i> Gray							x
<i>Helianthus scaberrimus</i> Nutt.		x	x				x
<i>Verbesina encelioides</i> var. <i>exauriculata</i> R. & G.						x	x
<i>Bidens tenuiseta</i> Gray							x
<i>Hymenopappus arenosus</i> Heller		x					x
<i>Bahia dissecta</i> (Gray) Britt.		x				x	x
<i>Chaenactis douglasii</i> (Hook.) H. & A.		x					x
<i>Actinea leptoclada</i> (Gray) Ktze.					x	x	x
<i>Dysodia papposa</i> (Vent.) Hitchc.		x					x
<i>Achillea millefolium</i> L.					x		x
<i>Chrysanthemum leucanthemum</i> L.							x
<i>Artemisia coloradensis</i> G.E.O.		x	x	x	x	x	x
<i>Artemisia frigida</i> Willd.			x	x	x	x	x
<i>Artemisia dracunculus</i> L.					x	x	
<i>Artemisia Wrightii</i> Gray				x	x	x	x
<i>Artemisia tridentata</i> Nutt.				x		x	x
<i>Senecio eremophilus</i> Richards							x
<i>Senecio multicapitatus</i> Greene							x
<i>Senecio mutabilis</i> Greene							x
<i>Senecio pseudoaureus</i> Rydb.							x
<i>Cirsium pulchellum</i> (Greene) Wootton & Standley		x					x
<i>Cirsium tracyi</i> Rydb.			x	x			x
<i>Tragopogon pratensis</i> L.		x					x
<i>Prenanthes racemosa</i> Michx.						x	

TABLE II (Continued)

<i>Crepis occidentalis</i> Nutt.						x			x		
<i>Lactuca pulchella</i> (Pursh) DC.											x
Total species	84	02	72	05	47	1	49	72	11	33	129

SUMMARY

A survey of the flora of the Chimney Rock area in the Pagosa-Piedra region, Archuleta County, Colorado was made in the summer of 1924 and the fall of 1931.

The Chimney Rocks and the top of Chimney Rock Mesa consisting of Pictured Cliffs sandstone overlying Lewis shale are an erosion remnant cut off by the Piedra River. Both formations belong to the Cretaceous period. The altitude of the area ranges from 6,450 feet near the Piedra River to 7,902 feet, which is the elevation of the highest Chimney Rock.

The area is divided into the foothill or yellow pine zone and the upper sonoran or pinyon-juniper zone. Climatological data for the former zone were assembled from Pagosa Springs, and for the latter from Ignacio.

The mean annual temperature for the foothill zone was 39.9°F. and for the upper sonoran zone 45.18°F. The mean temperature from May to September is 55.03°F. for the foothill zone and 60.8°F. for the upper sonoran zone. The frostless season for the former zone is 75 days and for the latter zone 105 days.

The mean annual rainfall in the foothill zone is 24.3 inches, and in the upper sonoran zone is 16.69 inches, with a seasonal distribution of 38% from November to March, and 43% from May to September in the former zone; and 33% from November to March, and 50% from May to September in the latter zone. June has the least rainfall for the year, and July has the greatest rainfall and the highest temperature in both zones.

The upper sonoran zone was best represented by the Eriogonum and pinyon-juniper associations. The foothill zone is divided into two belts, i.e., the "chaparral belt," consisting of the mixed shrub association, and the "pine belt," consisting of the Gutierrezia, sagebrush, Chrysothamnus, yellow pine, and Pseudotsuga associations belonging to the xerarch succession, and the Populus-Salix association belonging to the hydrarch succession. The associations were determined by observations made over the entire area while collecting plants, and by quadrat studies made in all except the last two plant associations.

Upon the shale slides could be traced the successional series of upper sonoran plant associations from the Eriogonum or xerophytic herb association through the mixed shrub to the pinyon-juniper association. Eriogonum lonchophyllum was the dominant

plant in the early stages of this xerarch succession.

The pinyon-juniper association on top of the Chimney Rock Mesa represented the climatic climax for the upper sonoran zone. The vegetation was divided into two habitats: (1) in the open and (2) beneath the pinyon tree. The rock cover of 20.58% and the plant cover of 30.48% in the open were the greatest for any plant association studied. Grasses formed two-thirds of the cover in the open. Bouteloua oligostachya, with a cover of 19.06%, dominated. Opuntia fragilis, Artemisia coloradensis and Leucelene ericoides were the dominant forbes. Out of a total plant cover of 12.96% under the pinyon, grasses had a total cover of 10.82%. Oryzopsis micrantha, having a cover of 6.32%, occurred on the north side and nearest the tree. Hilaria jamesii formed a circle outside of this about the tree.

Upon the exposed, highest part of the Mesa, where the Indian ruins had been excavated, were different plants from those found elsewhere on the Mesa. Most of these plants were weeds of which seven were introduced from Europe. Of these Bromus tectorum occurred in greatest abundance. Three of southwestern distribution occurred nowhere else in the area. Of these Sphaeralcea fendleri was a new record for Colorado.

The mixed shrub association occurred as a belt on the north-facing slope of Chimney Rock Mesa above the yellow pine and below the pinyon-juniper associations. This constituted an altitudinal reversal of associations so far as the usual order is concerned in Colorado. The mixed shrub association was divided into ridge and gulch habitats. Quercus gambellii was greatest in frequency and second in cover of all shrub species in both habitats. Except for Quercus and Symphoricarpos oreophilus the shrub species on the ridge and in the gulch were different. The southwest slopes and exposures in the entire area were the most xerophytic. Cercocarpus montanus was the dominant shrub on the southwest exposure of the ridge, and Amelanchier utahensis the dominant one on the northeast exposure. The shrubs in the gulch were the same as those to be given for the base of the east slope of the yellow pine association except Pachystima myrsinites, which seemed to be the most mesophytic shrub in the entire area.

Fendlera rupicola, Yucca baccata and Opuntia arborescens were the shrubs found on the extremely xerophytic southwest slopes of the area.

The yellow pine association, occurring at the lower elevations on all slopes, and occupying most of the area surveyed, was the climatic climax of the foothill zone. The yellow pine, Pinus scopulorum, and Quercus gambellii occurred with equal dominance in the association. Major studies were made near the top of the hill

on the xerophytic southwest-facing slope, on a flat hilltop of north exposure, and on a mesophytic east-facing slope. Herbs formed the dominant cover of the southwest-facing slope, where grasses formed two-thirds of the cover. Bouteloua curtipendula and Sitanion hystrix were the dominant grasses, and with them occurred Poa fendleriana and Aristida fendleriana. The dominant forbes were Actinea leptoclada, Chrysopsis bakeri, Artemisia wrightii and Psoralea tenuiflora. Aside from Quercus, the xerophytic shrubs Purshia tridentata and Cercocarpus montanus were the only ones listed.

On the flat hilltop of north exposure Quercus vreelandii was found. The principal herbs here were Wyethia arizonica, Penstemon glabrescens, Aristida fendleriana and Erigeron flagellaris.

On the east-facing slope shrubs formed the dominant cover. The greatest number of species were found at the base of the slope. The following were the dominant shrub species found here: Berberis fendleri, Rosa fendleri, Prunus melanocarpa and Symphoricarpos oreophilus. Quercus gambellii was dominant from near the base to the top of the slope. Wyethia arizonica, Erigeron macranthus, Anemone cylindrica and Aster laevis were the dominant forbes.

Great diversity of habitat may account for a larger number of plant species here than in the other xerarch associations. The yellow pine association, having a plant cover of 11.79%, was fourth in the associations studied.

The Chrysothamnus association occurred on the well drained alluvial deposits on the open south-facing and on a north exposure of the broad gulch leading north from the Chimney Rocks. Chrysothamnus graveolens formed almost a pure stand on the south-facing slope. The more mesophytic gulch habitat had several shrub species and had the aspect of a transition association.

The Pseudotsuga association was considered the physiographic climax because of its occurrence only on north- and east-facing slopes.

The Populus-Salix association, occurring along Piedra River and Devil Creek, was a closed association and had the largest number of species. This latter fact signifies that moisture is the limiting factor to abundant plant growth. The new species Grindelia exilifolia A. Nels. n. sp. was collected on the alluvial terrace to the south of Devil Creek and along the road on the west side of the opening from the gulch leading north from the base of the Chimney Rocks.

BIBLIOGRAPHY

1. Bates, C. G., Forest types in the Central Rocky Mountains as affected by climate and soil. U. S. Dept. Agri. Bull. 1233. 1924.
2. Cary, Merritt, A biological survey of Colorado. U.S.D.A. Bur. of Biol. Surv., North American Fauna No. 33. 1911.
3. Cooper, Wm. S., Broad sclerophyll vegetation of California. An ecological study of the chaparral and its related communities. Carnegie Inst. Wash. Pub. 319. 1922.
4. Coulter, J. M. and Nelson, Aven, New manual of the Central Rocky Mountains. New York. 1909.
5. Cowles, H. C., The causes of vegetative cycles. Bot. Gaz. 51: 161-183. 1911.
6. Day, P. C., Summary of the climatological data for the United States by sections, from the establishment of stations to 1922, inclusive. Reprint of Section 9. Western Colorado. U. S. Dept. Agri. Weather Bureau. 1922.
7. Gardner, J. H., The coal field between Durango, Colorado, and Monero, New Mexico. U. S. Geol. Survey Bull. 341. pp. 352-363. Plate XXIII. 1909.
8. Jeancon, J. A., Archeological research in the northeastern San Juan basin of Colorado during the summer of 1921. State Hist. and Nat. Hist. Soc. of Colo. and Univ. of Denver. 1922.
9. Kenoyer, Leslie A., A study of Raunkaier's law of frequency. Ecology 8: 341-349. 1927.
10. Nichols, George E., The plant association. Ecology 4: 11-23. 1923.
11. Pearson, G. A., Forest types in the southwest as determined by climate and soil. U. S. Dept. Agri. Technical Bull. 247. 1931.
12. Ramaley, Francis, Plant zones in the Rocky Mountains of Colorado. Science N. S. 26: 642-643. 1907.
13. Robbins, W. W., Native vegetation and climate of Colorado in their relation to agriculture. Agri. Exp. Sta. of the Colo. Agri. Coll. Bull. 224. pp. 56. 1917.
14. Rydberg, P. A., Flora of Colorado. Colo. Agri. Coll. Exp. Sta. Bull. 100. 1906.
15. _____, Flora of the Rocky Mountains and adjacent plains. New York. 1922.

16. _____, Vegetative life zones of the Rocky Mountain region.
Mem. N. Y. Bot. Gard. 1915. 6: 477-499. 1916.
17. Sherier, J. M., Climatological data. Colorado Section.
U. S. Dept. Agri. Weather Bureau. Vols. 28-35. 1923-1930.
18. Steiger, T. L., Structure of prairie vegetation. Ecology 11:
170-217. 1930.
19. Tidestrom, Ivar, Flora of Utah and Nevada. Smithsonian Institution, Washington. Contributions from the U. S. National Herbarium 25. 1925.
20. Vestal, A. G., Foothills vegetation in the Colorado Front Range. Bot. Gaz. 64: 353-385. 1917.
21. Wooton, E. O. and Standley, Paul C., Flora of New Mexico. Smithsonian Institution, Washington. Contributions from the U. S. National Herbarium 19. 1915.

